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ART. I.—*Contributions to Meteorology;* by ELIAS LOOMIS, Professor of Natural Philosophy in Yale College. Eighteenth paper. With a Map (Plate I).

[Read before the National Academy of Sciences, Nov. 14, 1882.]

Mean annual rain-fall for different countries of the globe.

MY sixteenth paper of "Contributions to Meteorology" contained a table showing the annual rain-fall for 713 stations from various parts of the globe, and also a chart showing the lines of equal rain-fall as well as I could determine them from the observations then collected. I however distinctly stated that for certain portions of the globe, and especially for the southern hemisphere, the observations were too few to enable us to draw the lines of equal rain-fall with confidence; and I requested that if any person should discover serious defects in my chart, he would communicate to me the observations which indicate these defects. In response to this request I have received communications from numerous sources, of which the following are the most important: The Meteorological Service of the Dominion of Canada; the Meteorological Institute of Norway; the United States Signal Service; Dr. Alexander Woeikoff of St. Petersburgh; Dr. A. von Danckelman of Leipzig; Dr. Benjamin A. Gould of Cordoba; Professor Orville A. Dewey of Rio de Janeiro; Dr. Mauricio F. Draenert of Bahia: and Henry B. Joiner of S. Paulo, Brazil. I have also received the published observations of rain-fall from a large number of

countries, of which those from Mexico, Japan, the East Indian Archipelago, and Australia, and those contained in the second edition of Schott's Rain Tables, have proved of the greatest value for my present purpose. I have carefully considered the criticisms which have been made upon my first paper, particularly those of Dr. Woeikoff (this Journal, May, 1882) and those of the editor of Nature (June 29, 1882).

The accompanying table shows the most important observations which I have thus far received, many of them being from new stations, while those from stations included in my former paper exhibit the results of a more extended period of observation. Column 1st contains the reference number; column 2d gives the name of the station; column 3d gives its elevation above the sea expressed in English feet; column 4th gives the latitude of the station and column 5th its longitude from Greenwich; column 6th shows the number of years of observation represented; column 7th shows the mean annual rain-fall expressed in English inches; and column 8th gives the authority for the results. In the last column, Schott's T. 2d ed. stands for Tables of the precipitation in rain and snow in the United States, by Charles A. Schott, 1881; Bol. Met. Mex. stands for Boletin Meteorologica Mexicana; Revista Ci. Mex. stands for Revista Cientifica Mexicana; Rev. de Engenh. stands for Revista de Engenharia; S. Paulo Rw. Co. stands for São Paulo Railway Company; Zeitsch. stands for Zeitschrift der Österreichischen Gesellschaft für Meteorologie; En. Met. Com. 28 stands for Contribution to the Meteorology of Japan No. 28, issued by the English Meteorological Committee; Q. J. Met. Soc. stands for Quarterly Journal of the London Meteorological Society; A. v. Danckelman stands for Meteorologischen Beobachtungen von Dr. A. von Danckelman; Russ. Met. Obs. stands for Russell's Rain Observations in New South Wales. The other abbreviations will probably be understood without particular explanation. This table might have been very much enlarged, but I have confined myself to those stations which were regarded as specially useful in revising my rain-chart. With the aid of the new materials thus collected I have prepared a new chart of the rain-fall which is believed to represent pretty well all the observations contained in my two tables.

If these two charts are carefully compared, a general resemblance will be readily perceived, particularly in the Northern Hemisphere. In North America there is a little change between Lake Superior and Hudson Bay; also in Yucatan and Central America. In South America the changes are much greater. The observations from the Argentine Republic indicate that the line of 50 inches rain-fall crosses the meridian of 60° in about latitude 27½° S.; and although the number of ob-

Mean Annual Rain-fall for various Stations.

No.	Station.	Elev. feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
1	Fort Peel's River	..	67° 32′ N	134 30 W	2½	53·88	Schott's T., 2d ed.
2	York Fact'y, Hud. B.	55	57 0 N	92 26 W	4	24·73	Canada Met. Obs.
3	Dunvegan, N.W.Ter.	1000	56 0 N	118 20 W	..	15·26	Can. Met. Office.
4	Belle Isle	405	51 53 N	55 22 W	..	55·07	do.
5	Lillooet, Brit. Col.	..	50 42 N	122 2 W	3	15·26	Canada Met. Obs.
6	Spence's Bridge, B.C.	760	50 25 N	121 30 W	4	10·14	do.
7	Nicola Lake, Br. Col.	2100	50 16 N	120 43 W	3	11·99	do.
8	Meadow Lea, Man.	825	50 7 N	97 40 W	..	24·64	Can. Met. Office.
9	Ossowa, Manitoba	..	50 6 N	98 15 W	..	27·14	do.
10	Poplar Heights, Man.	..	50 5 N	97 50 W	2	25·45	Canada Met. Obs.
11	Rockwood, Manitoba	..	50 5 N	97 12 W	2	17·60	do.
12	Mazatlan, Mex.	249	23 11 N	106 0 W	2	45·91	Bol. Met. Mex.
13	Zacatecas, Mex.	8187	22 44 N	102 33 W	3	25·65	do.
14	San Luis Potosi, Mex.	6202	22 9 N	100 58 W	3	16·30	do.
15	Pabellon, Mex.	6314	22 4 N	102 11 W	3	20·82	do.
16	Leon, Mex.	5901	21 6 N	101 30 W	3	28·26	do.
17	Guanaxuato, Mex.	6761	21 1 N	100 48 W	1	20·65	do.
18	Jalisco, Mex.	..	20 55 N	105 12 W	1	49·41	do.
19	San Juan del Rio	..	20 24 N	99 39 W	1	22·33	do.
20	Campeche, Mex.	..	19 54 N	90 24 W	1	45·56	do.
21	Teziutlan, Mex.	..	19 46 N	97 22 W	3	66·12	do.
22	Patzcuaro, Mex.	7015	19 31 N	101 31 W	2	44·77	do.
23	Mirador, Mex.	3600	19 15 N	96 40 W	12	83·86	Schott's T., 2d ed.
24	Puebla, Mex.	7112	19 3 N	98 11 W	3	40·24	Bol. Met. Mex.
25	Tuxpam, Mex.	..	19 0 N	97 7 W	3	59·61	do.
26	Colima, Mex.	1664	18 46 N	103 20 W	12	41·73	Revista Ci. Mex.
27	Tlacotalpam, Mex.	11	18 37 N	95 39 W	2	90·28	Bol. Met. Mex.
28	Oaxaca, Mex.	5072	17 3 N	96 40 W	3	30·21	do.
29	Aspinwall, N. Gren.	7	9 23 N	79 53 W	6	121·60	Schott's T., 2d ed.
30	Heredia, Costa Rica	3837	10 0 N	84 0 W	1	47·64	do.
31	Caracas, Venezuela	2923	10 31 N	66 55 W	1	37·01	Smith. Rep., 1867.
32	Medellin, Colombia	..	6 38 N	76 35 W	2	63·36	Sig. Ser. Int. Obs.
33	Paramaribo	..	5 49 N	55 12 W	2	91·03	do.
34	Manaos, Brazil	121	3 8 S	60 0 W	1	55·20	Zeitsch., viii, 267.
35	Fortalera, Ceara	..	3 43 S	38 29 W	28	58·62	W. M. Roberts.
36	Iquitos, Peru	320	3 44 S	73 8 W	1½	103·28	Schott's T., 2d ed.
37	Pernambuco	10	8 4 S	34 52 W	4	108·40	Zeitsch, xiv, 216.
38	S. Bento das Lages	98	12 37 S	38 40 W	1½	80·80	Rev. de Engenh.
39	Bahia, Brazil	..	13 0 S	38 32 W	1	83·08	do.
40	Sabara, Brazil	2280	19 54 S	44 30 W	25	64·45	W. M. Roberts.
41	Rio de Janeiro, Brazil	..	22 54 S	43 8 W	17	43·78	do.
42	S. Paulo, Brazil	2393	23 33 S	46 37 W	3	53·23	Henry B. Joyner.
43	Serra do Cubatao	2625	23 45 S	46 30 W	6	137·80	do.
44	Santos, Brazil	0	24 0 S	46 22 W	8	94·50	S. Paulo Rw. Co.
45	Alto da Serra	..	24 0 S	49 20 W	9	140·30	Prof. O. A. Derby.
46	Salta, Rep. Argentina	..	24 45 S	65 27 W	4½	27·01	Dr. B. A. Gould.
47	Villa Formosa, R. Ar.	..	26 12 S	58 5 W	2½	72·72	do.
48	Tucuman, Rep. Arg.	141	26 46 S	65 29 W	4½	35·40	do.
49	Corrientes, R. Arg.	..	27 19 S	58 56 W	7	58·58	do.
50	Pilciao, R. Arg.	..	27 30 S	66 36 W	5	39·17	do.
51	Santiago del Estero	..	27 44 S	64 23 W	6	19·92	do.
52	Goya, R. Arg.	..	29 12 S	59 22 W	6	46·22	do.
53	Saladillo, R. Arg.	..	29 S	67 W	3	17·87	do.
54	Rioja, R. Arg.	..	29 18 S	67 22 W	2½	11·93	do.
55	Curuzu Cuatia, R. A.	..	29 54 S	58 9 W	1½	51·46	do.
56	Villa Hernandarias	..	31 15 S	59 41 W	5	39·80	do.
57	Concordia, R. Arg.	..	31 23 S	58 2 W	3	46·10	do.

Mean Annual Rain-fall for various Stations.

No.	Station.	Elev. feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
58	Cordoba, Rep. Arg.	1240	31° 25′ S	64° 11′ W	9½	27·80	Dr. B. A. Gould.
59	San Juan, Rep Arg.	..	31 27 S	68 20 W	5	2·83	do.
60	Parana, Rep. Arg.	..	31 44 S	60 24 W	6	36·77	do.
61	Mendoza, Rep. Arg.	2559	32 53 S	68 52 W	4	7·15	do.
62	Rosario, Rep. Arg.	..	32 55 S	60 39 W	5	38·50	do.
63	Rio Cuarto, R. Arg.	..	33 7 S	64 21 W	1	29·21	do.
64	Nueva Palmira, R. A.	..	33 47 S	58 16 W	4½	27·24	do.
65	Tatay, Rep. Arg.	..	34 14 S	59 54 W	5½	33·78	do.
66	S. Antonio d'Areco	..	34 15 S	59 30 W	3	31·38	do.
67	Chacra Matanzas	..	34 25 S	58 26 W	5	36·58	do.
68	25 de Mayo, R. Arg.	..	35 20 S	62 0 W	1½	37·48	do.
69	Salado, Rep. Arg.	..	35 40 S	59 6 W	3½	30·94	do.
70	Dolores, Rep. Arg.	..	36 19 S	58 14 W	3½	33·27	do.
71	Tandil, Rep. Arg.	..	37 13 S	59 10 W	3½	34·45	do.
72	Bahia Blanca, R. Ar.	62	38 44 S	62 11 W	22	19·25	do.
73	Ushuaia, Rep. Arg.	..	54 53 S	68 10 W	3	19·72	do.
74	Alten, Norway	43	69 58 N	23 17 E	8	10·46	Dr. Henry Mohn.
75	Südvaranger, Norw.	66	69 40 N	30 11 E	7–8	14·39	do.
76	Tromsö, Norway	50	69 39 N	18 58 E	8–9	31·86	do.
77	Fagernes, Norway	25	68 27 N	17 28 E	8	19·72	do.
78	Lödingen, Norway	44	68 24 N	16 1 E	7	47·39	do.
79	Varö, Norway	39	67 41 N	12 37 E	2–3	24·19	do.
80	Bodö, Norway	15	67 17 N	14 24 E	12	32·39	do.
81	Ranen, Norway	43	66 12 N	13 32 E	8	39·74	do.
82	Brönö, Norway	35	65 28 N	12 14 E	8–9	32·65	do.
83	Ytteröen, Norway	249	63 49 N	11 14 E	9	21·04	do.
84	Christiansund, Norw.	50	63 7 N	7 45 E	18	33 47	do.
85	Köros, Norway	2064	62 35 N	11 23 E	7–8	15·73	do.
86	Aalesund, Norway	47	62 29 N	6 9 E	14	45·20	do.
87	Dovre, Norway	2110	62 5 N	9 8 E	10–11	14·30	do.
88	Domsten, Norway	36	61 53 N	5 40 E	5	74·02	do.
89	Florö, Norway	26	61 36 N	5 2 E	6	75·28	do.
90	Sogndal, Norway	109	61 18 N	7 3 E	9	27·97	do.
91	Flesje, Norway	16	61 8 N	6 27 E	8	52·75	do.
92	Grunheim, Norway	1251	61 6 N	8 58 E	8–9	21·35	do.
93	Leisdal, Norway	16	61 6 N	7 27 E	10	12·22	do.
94	Birid, Norway	419	60 58 N	10 35 E	5	23·86	do.
95	Bergen, Norway	57	60 24 N	5 20 E	14	72·24	do.
96	Kidsvold, Norway	615	60 22 N	11 13 E	10–11	30·84	do.
97	Ullensvang, Norway	35	60 20 N	6 40 E	6–7	39·69	do.
98	Hole, Norway	336	60 4 N	10 16 E	5	19·74	do.
99	Lauglien, Norway	926	60 4 N	10 31 E	6	41·08	do.
100	Bjomholt, Norway	824	60 3 N	10 39 E	..	42 02	do.
101	Christiania, Norway	80	59 55 N	10 45 E	42	26·93	do.
102	Aas, Norway	289	59 37 N	10 47 E	6	27·53	do.
103	Fredrikstad, Norway	18	59 13 N	10 56 E	3–7	31·60	do.
104	Valle, Norway	1039	59 12 N	7 32 E	3–4	36·80	do.
105	Skudesnes, Norway	13	59 9 N	5 16 E	14	42·84	do.
106	Sandösund, Norway	27	59 5 N	10 28 E	14	23·15	do.
107	Mandal, Norway	54	58 2 N	7 27 E	14	44·88	do.
108	Dalmatow, Russia	..	56 14 N	62 37 E	14	12·64	Dr. A. Woeikoff.
109	Astrakhan, Russia	55	46 21 N	48 2 E	32	5·71	do.
110	Low. Syr Daria, Rus.	..	46 N	62 E	5	5·12	do.
111	F. Alexandrowski, R.	..	44 27 N	50 8 E	13	4·49	do.
112	Alexandropol, Russia	5010	40 47 N	43 35 E	18	14·96	do.
113	Krasnovodsk, Russia	..	40 0 N	53 9 E	3	15·37	Met. Annalen.
114	Ura Tübe, Russia	..	41 30 N	68 13 E	1	12·95	do.

Mean Annual Rain-fall for various Stations.

No.	Station.	Elev. feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
115	Taschkent, Russia	1588	41° 20 N	69° 18 E	8	12·28	Met. Annalen.
116	Samarkand, Russia	2378	39 39 N	66 57 E	1	13·54	do.
117	Pendshekent, Russia	3163	39 28 N	67 33 E	1	12·44	do.
118	I. Ashur Ade, Russia	..	36 54 N	53 50 E	6	17·80	Dr. A. Woeikoff.
119	Wernyj, Russia	2402	43 16 N	76 53 E	2	18·44	Met. Annalen.
120	Yokohama, Japan	..	35 27 N	139 40 E	4	85·27	En. Met. Com., 28.
121	Cape Sagami, Japan	..	35 8 N	139 41 E	4	48·14	do.
122	Awadji, Japan	..	34 37 N	135 0 E	3	38·13	do.
123	Rock Island, Japan	..	34 34 N	138 57 E	4	60·94	do.
124	Isumi, Japan	..	34 17 N	135 0 E	2	47·61	do.
125	Isaki, Japan	..	33 58 N	131 1 E	2	54·27	do.
126	Isauri Sima, Japan	..	33 53 N	132 38 E	1	28·16	do.
127	Oosima, Japan	..	33 28 N	135 52 E	4	71·43	do.
128	Siwo Misaki, Japan	..	33 26 N	135 46 E	4	64·78	do.
129	Nagasaki, Japan	..	32 43 N	129 46 E	4	40·64	do.
130	Saton Misaki, Japan	..	30 58 N	130 40 E	4	52·12	do.
131	Zikawei, China	..	31 12 N	121 26 E	8	42·44	Zeitsch., xvii, 16.
132	Hongkong, China	..	22 16 N	114 10 E	12	84·60	Zeitsch., viii, 72.
133	Manilla, Phil. Is.	..	14 36 N	120 40 E	19	75·05	Various sources.
134	Bangkok, Siam	..	13 43 N	100 25 E	10	67·04	Q J.Met.Soc. v,88.
135	Saigun, Siam	..	10 48 N	106 40 E	1	58·42	Zeitsch., vii, 23.
136	Bohol, Phil. Is.	..	9 55 N	124 32 E	2	49·47	Zeitsch., v, 69.
137	Linao, Phil. Is.	..	8 5 N	125 45 E	1	150·72	do.
138	Serang, Java	102	6 7 S	106 8 E	3	82·05	Dr.P.A. Bergsma.
139	Onrust, Java	..	6 1 S	106 46 E	3	71·50	do.
140	Batavia, Java	23	6 11 S	106 50 E	3	73·31	do.
141	M. Cornelis, Java	46	6 13 S	106 54 E	3	81·74	do.
142	Buitenzorg, Java	869	6 36 S	106 47 E	3	203·24	do.
143	Tjandjoer, Java	1542	6 49 S	107 8 E	3	114 10	do.
144	Telaga P., Java	5105	7 10 S	107 25 E	2	167·01	do.
145	Soekawana, Java	5062	6 45 S	107 38 E	3	115·95	do.
146	Soemedang, Java	1450	6 50 S	107 57 E	2	122·09	do.
147	Manondjaja, Java	810	7 20 S	108 20 E	2	131·34	do.
148	Tjilatjap, Java	0	7 44 S	109 0 E	2	161·64	do.
149	Kedong K., Java	148	7 41 S	110 2 E	3	115·16	do
150	Madjalengka, Java	472	6 48 S	108 15 E	2	138·43	do.
151	Tegal, Java	0	6 51 S	109 8 E	3	77·72	do.
152	Pekalongan, Java	0	6 53 S	109 40 E	3	104·97	do.
153	Pelantoengan, Java	2273	7 6 S	109 59 E	3	192·98	do.
154	Semarang, Java	13	6 58 S	110 25 E	3	90·91	do.
155	Rembang, Java	0	6 45 S	111 20 E	3	56·30	do.
156	Toeban, Java	0	6 52 S	112 5 E	3	62·80	do.
157	Oenarang, Java	1027	7 8 S	110 23 E	3	206·16	do.
158	Willem I., Java	1562	7 16 S	110 24 E	3	99·81	do.
159	Salatiga, Java	1933	7 20 S	110 30 E	3	117·72	do.
160	Magelang, Java	1257	7 29 S	110 13 E	3	137·13	do.
161	Djokjokarta, Java	371	7 48 S	110 21 E	3	95·79	do.
162	Patjitan, Java	23	8 12 S	111 5 E	2	79·10	do.
163	Klatten, Java	692	7 42 S	110 35 E	3	91·85	do.
164	Bojolali, Java	1300	7 32 S	110 35 E	3	127·56	do.
165	Soerakarta, Java	302	7 34 S	110 49 E	3	95·00	do.
166	Madioen, Java	220	7 37 S	111 31 E	2	69·96	do.
167	Ngawi, Java	203	7 24 S	111 26 E	3	90·83	do.
168	Malang, Java	1476	7 57 S	112 38 E	3	97·05	do.
169	Modjokerto, Java	95	7 28 S	112 25 E	3	73·31	do.
170	Soerabaja, Java	0	7 14 S	112 44 E	3	73·00	do.
171	Grissee, Java	0	7 10 S	112 39 E	3	69·06	do.

Mean Annual Rain-fall for various Stations.

No.	Station.	Elev. feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
172	Pasoeroean, Java	13	7 38 S	112 56 E	3	57·92	Dr. P. A. Bergsma.
173	Probolingo, Java	33	7 44 S	113 13 E	3	50·20	do.
174	Loemadjang, Java	177	8 7 S	113 14 E	2	68·35	do.
175	Besoeki, Java	7	7 43 S	113 41 E	3	52·28	do.
176	Sitoebondo, Java	262	7 41 S	114 2 E	3	50·95	do.
177	Maësan, Java	1214	8 0 S	113 50 E	3	109·65	do.
178	Banjoewangi, Java	16	8 13 S	114 23 E	3	58·98	do.
179	Bangkalan, Madoera	16	7 2 S	112 44 E	3	84·33	do.
180	Pamekasan, Madoera	0	7 10 S	113 30 E	3	70·12	do.
181	Soemenep, Madoera	0	7 3 S	113 54 E	3	68·23	do.
182	Telok. B., Sumatra	0	5 26 S	105 16 E	3	89·68	do.
183	Benkoelen, Sumatra	0	3 47 S	102 14 E	3	124·41	do.
184	Padang, Sumatra	0	0 58 S	100 25 E	3	182·24	do.
185	Loeboeselassi. Sum.	1017	0 57 S	100 38 E	2	150·28	do.
186	Solok, Sumatra	1234	0 48 S	100 40 E	3	90·32	do.
187	Padang P., Sumatra	2560	0 30 S	100 30 E	2	211·14	do.
188	Fort de Kock, Sum.	3041	0 21 S	100 28 E	3	81·22	do.
189	Pajakombo, Sumatra	1630	0 15 S	100 47 E	3	86·42	do.
190	Rau, Sumatra	977	0 32 N	100 3 E	2	87·88	do.
191	Padang S., Sumatra	929	1 23 N	99 15 E	2	107·21	do.
192	Siboga, Sumatra	0	1 44 N	98 46 E	3	187·87	do.
193	Singkel, Sumatra	0	2 17 N	97 45 E	3	180·62	do.
194	Kotta Radja, Sumatra	0	5 32 N	95 20 E	3	69·18	do.
195	Edi, Sumatra	0	5 53 N	97 46 E	2	83·19	do.
196	Agnieta P., Sumatra	--	4 9 N	98 9 E	2	100·08	do.
197	Koeala, S., Sumatra	--	4 18 N	98 3 E	2	99·41	do.
198	Medan, Sumatra	46	3 35 N	98 41 E	2	95·20	do.
199	Medan P., Sumatra	46	3 35 N	98 41 E	3	87·96	do.
200	Sipoet. Sumatra	--	3 30 N	98 38 E	2	122·44	do.
201	Bengkalis, Sumatra	0	1 28 N	102 6 E	2	105·32	do.
202	Djambi, Sumatra	--	1 35 S	103 36 E	3	102·09	do.
203	Palembang, Sumatra	--	2 59 S	104 45 E	3	120·16	do.
204	Tebing T., Sumatra	--	3 36 S	103 4 E	2	126·07	do.
205	Bandar, Sumatra	--	4 5 S	103 22 E	2	125·51	do.
206	Lahat. Sumatra	--	3 48 S	103 31 E	2	151·02	do.
207	Tandjong P., Riouw	0	0 56 N	104 25 E	3	105·79	do.
208	Muntok, Bangka	0	2 3 S	105 9 E	3	132·64	do.
209	Tandjong P., Billiton	0	2 45 S	107 33 E	3	129·84	do.
210	Singkawang, Borneo	0	0 55 N	108 59 E	2	111·56	do.
211	Pontianak, Borneo	--	0 1 N	109 20 E	3	121·58	do.
212	Sintang, Borneo	--	0 7 N	111 32 E	2	147·01	do.
213	Bandjermasin, Bor.	--	3 19 S	114 35 E	3	97·99	do.
214	Pengaron, Borneo	--	3 15 S	115 15 E	2	102·92	do.
215	Amoenthai, Borneo	--	2 15 S	115 10 E	2	97·52	do.
216	Barabei, Borneo	--	2 17 S	115 16 E	2	115·16	do.
217	Makassar, Celebes	0	5 8 S	119 24 E	3	131·81	do.
218	Pangkadjene, Celeb.	0	4 51 S	119 32 E	2	154·29	do.
219	Balung N., Celebes	0	5 7 S	120 14 E	2	101·42	do.
220	Menado, Celebes	13	1 30 N	124 50 E	2	98·86	do.
221	Ternate Island	10	0 47 N	127 22 E	2	93·51	do.
222	Amboina Island	0	3 42 S	128 10 E	3	165·44	do.
223	Banda Island	0	4 32 S	129 53 E	3	117·92	do.
224	Timor K. Island	49	10 10 S	123 34 E	2	52·36	do.
225	Kuka, Cen. Africa	--	13 10 N	14 30 E	--	33·00	Guyot's Phy. Atl.
226	Christiansb'g, W. Af.	--	5 24 N	0 10 W	--	144·00	do.
227	Gabun, W. Africa	287	0 25 N	9 35 E	4	94·17	Zeitsch., xvi–xvii.
228	Chinchoxo, W. Africa	39	5 9 S	12 3 E	2	42·41	A. v Danckelman.

Mean Annual Rain-fall for various Stations.

No.	Station.	Elev. feet.	Lat.	Long.	Years. Obs.	Rain. Inches.	Authority.
229	Palmerston, S. Aust.	70	12° 26′ S	130° 52′ E	10	63·69	Todd's Met. Obs.
230	Southport, S. Aust.	..	12 44 S	131 0 E	4	72·18	do.
231	Yam Creek, S. Aust.	..	13 29 S	131 35 E	4	54·43	do.
232	Pt. Macquarie, N.S.W.	..	31 25 S	152 54 E	16	63·75	Russ. Met. Obs.
233	Kurraj. Hts., N.S.W.	..	33 33 S	150 45 E	13	53·90	do.
234	Sydney, N.S.W.	..	33 51 S	151 12 E	22	51·46	do.
235	Botany, N.S.W.	..	33 56 S	151 12 E	11	53·30	do.
236	Cordeaux R., N.S.W.	..	34 19 S	150 44 E	9	59·89	do.
237	Cape St. Geo., N.S.W.	..	35 12 S	150 45 E	14	56·12	do.
238	Milton, N.S.W.	..	35 14 S	150 20 E	4	50·52	do.
239	Pine Creek, S. Aust.	..	13 52 S	131 56 E	4	46·38	Todd's Met. Obs.
240	R. Katherine, S. Aust.	..	14 23 S	132 17 E	4	43·91	do.
241	Daly Waters, S. Aust.	..	16 17 S	133 29 E	4	31·66	do.
242	Melrose, S. Aust.	..	32 46 S	138 8 E	12	26 82	do.
243	Pewsey Vale, S. Aus.	..	34 36 S	138 58 E	4	28·40	do.
244	Mt. Pleasant, S. Aust.	..	34 46 S	139 3 E	4	27·62	do.
245	Gummeracha, S. Aus.	..	34 47 S	138 55 E	11	32·94	do.
246	Charleston, S. Aust.	..	34 58 S	138 51 E	15	32·99	do.
247	Mt. Lofty, S. Aust.	..	35 0 S	138 43 E	21	42·37	do.
248	Mt. Barker, S. Aust.	..	35 4 S	138 51 E	19	29·59	do.
249	Willunga, S. Aust.	..	35 16 S	138 31 E	18	26·66	do.
250	Yankalilla, S. Aust.	..	35 25 S	138 19 E	12	27·12	do.
251	Penola, S. Aust.	..	37 21 S	140 50 E	19	28·25	do.
252	Mt. Gambier, S. Aus.	130	37 46 S	140 46 E	19	31·80	do.
253	C. N'thumberl'd, S.A.	117	38 4 S	140 39 E	13	28·03	do.
254	Maryland, N.S.W.	..	28 36 S	152 5 E	11	34·80	Russ. Met. Obs.
255	Tenterfield, N.S.W.	..	29 5 S	152 4 E	10	31·07	do.
256	Grafton, N.S.W.	..	29 43 S	152 56 E	10	36·90	do.
257	Armidale, N.S.W.	..	30 34 S	151 46 E	16	35·62	do.
258	Mudgee, N.S.W.	..	32 35 S	149 35 E	9	26·74	do.
259	W. Maitland, N.S.W.	..	32 47 S	151 35 E	12	35·37	do.
260	Newcastle, N.S.W.	..	32 55 S	151 50 E	19	47·64	do.
261	Orange, N.S.W.	..	33 18 S	149 9 E	10	39·18	do.
262	Mt. Victoria, N.S.W.	..	33 36 S	150 15 E	8	37·47	do.
263	Windsor, N.S.W.	..	33 36 S	150 49 E	18	33·61	do.
264	Young, N.S.W.	..	34 18 S	148 21 E	8	28·66	do.
265	Mossvale, N.S.W.	..	34 32 S	150 23 E	8	45·45	do.
266	Goulburn, N.S.W.	..	34 45 S	149 45 E	17	26·79	do.
267	Albury, N.S.W.	..	36 6 S	147 0 E	17	28·03	do.
268	Eden, N.S.W.	..	37 0 S	149 59 E	12	39·29	do.
269	Kooringa, S. Aust.	..	33 42 S	138 59 E	21	17·45	Todd's Met. Obs.
270	Bungaree, S. Aust.	..	33 44 S	138 31 E	20	21·61	do.
271	Clare, S. Aust.	..	33 50 S	138 37 E	18	24·93	do.
272	Auburn, S. Aust.	..	34 2 S	138 38 E	15	24·50	do.
273	Wallaroo, S. Aust.	..	33 54 S	137 38 E	15	13·59	do.
274	Kapunda, S. Aust.	..	34 20 S	139 0 E	19	20·25	do.
275	Gawler, S. Aust.	..	34 35 S	138 45 E	18	18·97	do.
276	Adelaide, S. Aust.	..	34 57 S	138 35 E	41	21·31	do.
277	Strathalbyn, S. Aust.	..	35 16 S	138 55 E	19	18·84	do.
278	Goolwa, S. Aust.	..	35 29 S	138 47 E	16	17·21	do.
279	Meningie, S. Aust.	..	35 41 S	139 19 E	15	19·27	do.
280	Robe, S. Aust.	..	37 3 S	139 42 E	19	24·69	do.
281	Bourke, N.S.W.	..	30 3 S	145 58 E	8	15·45	Russ. Met. Obs.
282	Narrabri, N.S.W.	..	30 20 S	149 46 E	11	24·45	do.
283	Wilcannia, N.S.W.	..	31 31 S	143 23 E	8	11·09	do.
284	Cassilis, N.S.W.	..	32 0 S	150 0 E	10	23·72	do.
285	Scone, N.S.W.	..	32 4 S	150 53 E	7	22·27	do.

Mean Annual Rain-fall for various Stations.

No.	Station.	Elev. feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
286	Muswellbr'k, N.S.W.	..	32° 17 S	150° 53 E	7	19·00	Russ. Met. Obs.
287	Dubbo, N.S.W.	..	32 18 S	148 35 E	9	20·39	do.
288	Bathurst, N.S.W.	..	33 24 S	149 37 E	19	24·62	do.
289	Wentworth, N.S.W.	..	34 8 S	142 0 E	16	11·55	do.
290	Waggawagga, N.S.W	..	35 8 S	147 24 E	7	23·89	do.
291	Murray Downs, "	..	35 16 S	143 41 E	16	15·59	do.
292	Queanbeyan, N.S.W.	..	35 20 S	149 15 E	10	23·91	do.
293	Deniliguin, N.S.W.	..	35 32 S	145 2 E	20	16·50	do.
294	Cooma, N.S.W.	..	36 12 S	149 9 E	16	19·09	do.
295	Charl. Waters, S. Au.	..	25 50 S	134 57 E	4	8·83	Todd's Met. Obs.
296	Peake, S. Aust.	..	28 4 S	135 50 E	4	7·00	do.
297	Strangw. Spr., S. A.	..	29 11 S	136 33 E	4	6·12	do.
298	Stuart's Creek, S. A.	..	29 45 S	137 5 E	3	8·17	do.
299	Farina, S. Aust.	..	30 4 S	138 14 E	1	6·59	do.
300	Arrowie, S. Aust.	..	30 53 S	139 19 E	3	7·49	do.
301	Beltana, S. Aust.	..	30 58 S	138 27 E	4	8·32	do.
302	Wirrialpa, S. Aust.	..	31 1 S	138 52 E	4	6·94	do.
303	Wintabatingana, "	..	31 20 S	138 18 E	1	8·60	do.
304	Moonaree, S. Aust.	..	31 54 S	135 34 E	2	9·44	do.
305	Port Augusta, S. A.	..	32 29 S	137 45 E	20	8·70	do.
306	Moorna, S. Aust.	..	34 9 S	141 42 E	3	7·87	do.
307	Paringa, S. Aust.	..	34 10 S	140 44 E	7	9·94	do.
308	Goorimpa, N.S.W.	..	30 22 S	144 1 E	2	9·34	Russ. Met. Obs.
309	Tarella, N.S.W.	..	30 55 S	143 0 E	4	9·67	do.
310	Weinteriga, N.S.W.	..	32 8 S	142 52 E	4	9·26	do.
311	Teryawynia, N.S.W.	..	32 20 S	143 20 E	4	9·99	do.
312	Netley, N.S.W.	..	32 53 S	142 20 E	4	9·04	do.
313	Geraldton, W. Aust.	..	28 44 S	114 44 E	2	16·90	Fraser's Met. Ob.
314	Newcastle, W. Aust.	..	31 38 S	116 33 E	2	16·70	do.
315	Northam, W. Aust.	..	31 41 S	116 45 E	2	11·30	do.
316	York, W. Aust.	..	31 52 S	116 47 E	2	16·15	do.
317	Guildford, W. Aust.	..	31 55 S	115 56 E	2	38·25	do.
318	Perth, W. Aust.	..	31 57 S	115 52 E	4	32·58	do.
319	Freemantle, W. Aus.	..	32 2 S	115 42 E	2	26 45	do.
320	Pinjarra, W. Aust.	..	32 34 S	115 52 E	2	35·55	do.
321	Banburg, W. Aust.	..	33 18 S	115 32 E	2	41·90	do.
322	Vasse, W. Aust.	..	33 32 S	115 28 E	2	27·75	do.
323	Albany, W. Aust.	..	35 0 S	117 53 E	2	35·55	do.

servations from the interior of South America is very small, they seem to indicate that (with a few exceptions of limited extent) the entire central and northern portions of South America, east of the Andes, have a rain-fall exceeding 50 inches. The observations from Iquitos and San Antonio indicate a rain-fall of more than 75 inches for the eastern slope of the Andes; but many more observations are needed before the limits of the rain-fall of 50 inches and 75 inches can be satisfactorily assigned. In Europe the principal change is in Norway, the area of 25 inches rain-fall having been made too great on my former chart. In Central Asia I have made considerable change in the curve of 10 inches rain-fall, but this curve is one which it is specially difficult to trace satisfactorily, partly on account of the scarcity

of observations, but especially because there are very extensive regions where the rain-fall does not much exceed 10 inches. Some change has been made in the East Indian Archipelago required by the three years' observations of Dr. Bergsma. The changes in Central Australia are explained by the fact that when I prepared my former chart, the observations which were available were few in number and most of them included a period of only one year. The observations since received appear to indicate that throughout the whole interior of Australia, the average annual rain-fall is less than 10 inches. In Central Africa the present chart shows a greater rain-fall than the former one. Some of the changes are based upon new observations, and others have been made in deference to the judgment of my critics.

It is hoped that this revised rain-chart may be found less imperfect than the preceding. I do not expect, however, that it will be found perfect, and I urgently renew the request contained in my former paper that if any person whose attention is attracted to this map should discover in it serious defects, he will communicate to me the observations which indicate these defects. I propose hereafter to publish all additional observations of rain-fall which I may be able to obtain, so far as they indicate the necessity of changes in the present rain-chart, and if this chart should be found greatly in error, I intend to issue a revised edition of it.

Relation of rain-areas to areas of low pressure.

In former papers I have examined the cases in which a rain-fall of two inches in eight hours has occurred at any of the stations of the U. S. Signal Service, and also the cases in which the aggregate rain-fall at all the stations was unusually great. This examination has shown a marked difference between the effect of a great rain-fall in the northern and southern portions of the United States. South of the parallel of 36° we find that a rain-fall of two inches in eight hours occurs four times as frequently as it does north of that parallel, allowance being made for the difference in the number of stations. Also south of 36° these great rain-falls are not generally accompanied by any considerable depression of the barometer; but there is a cyclonic movement of the winds about the rain-area, accompanied by a small depression of the barometer. In a few cases the barometer stands above its mean height; the cyclonic motion of the winds is not distinctly marked, and the winds seem to be controlled by an area of high pressure prevailing north of 36°.

In the northern portion of the United States, great rain-falls appear to be always under the influence of an area of low pressure. The average distance of the principal rain-centers from

the center of low pressure is nearly 400 miles; they are generally on the east side of the low center, and are most frequently found nearly in the direction of the average progress of storm tracks. There is, then, an intimate connection between the rain-fall and the direction of a storm's progress; and the precipitation of the vapor of the air is apparently the chief source of that maintaining power which is necessary to sustain the action of violent storms. The direction of movement and rate of progress of an area of low pressure do not, however, depend simply upon the amount of rain-fall and position of the rain-areas within the limits of the area of low pressure, but also upon the existing distribution of pressure, temperature and humidity not only within the limits of the storm, but throughout an extensive region surrounding it on all sides.

In order to prosecute this enquiry under different geographical influences, I have prepared tables showing for a series of years the principal rain-falls in Europe. I selected from the Bulletin of International Meteorological Observations all those cases in which a rain-fall of two inches in twenty-four hours was reported at any station during the years 1878, 9 and 80. These cases are 233 in number, and the stations at which more than three cases of these great rain-falls occurred are shown in the following table. Column 2d shows the latitude of the station;

Station.	Lat.	Elev'n feet.	No. of Cases.	Station.	Lat.	Elev'n feet.	No. of Cases.
Trieste	45° 39′	85	26	Puy de Dome	45° 46′	4813	6
Udine	46 4	380	13	Moncalieri	44 59	853	6
Rochefort	45 56	30	12	Pola	44 51	105	6
Genoa	44 25	157	12	Com. de Greasque	43 25	1056	6
Valona	40 27	----	12	Mondovi	44 22	1824	5
Pic du Midi	42 16	7763	11	Carcassonne	43 13	384	5
Santiago	42 53	863	9	Bergen	60 24	49	4

column 3d its elevation in feet above the sea, and column 4th the number of cases in which a rain-fall of two inches in twenty-four hours was reported, at the station named.

The twelve cases of heavy rain reported at Rochefort are believed to be erroneous. They all occurred in the six months from June to November, 1880, and the error is supposed to have resulted from the fact that the rain-fall was measured in tenths of a millimeter, but was reported in such a way that the numbers were understood to represent millimeters, thus making the rain-fall ten times too great. Of the other thirteen stations, all but one are in the south of Europe, and show unequivocally the influence of local causes; two of the stations being on mountains and the others being in the neighborhood of mountains where the mean annual rain-fall is unusually great.

The following table contains a complete list of the cases for 1879. Column 1st gives the number of reference; column 2d, the date of observation; column 3d, the station of heavy rain-fall; column 4th, its latitude; column 5th, its longitude from Greenwich; column 6th, its elevation (in English feet) above sea level; column 7th, the rain-fall in twenty-four hours expressed in English inches; column 8th, the height of the barometer, reduced to sea level; column 10th, the direction of the wind at the date of observation; column 9th, its direction twenty-four hours previous; and column 11th, shows the direction of the given station from the center of low pressure with which it is believed to have been associated.

The average height of the barometer at the time of these heavy rains was 29·8 inches, and in only twenty-six cases was the barometer below 29·75 inches. In eleven cases the barometer at the station of greatest rain was above 30 inches; but in eight of these eleven cases, although the barometer was above its mean height, it was from three-tenths to seven-tenths of an inch lower than it was in some other part of Europe. Also in eight of these cases, there was a low center within a distance of about 1000 miles where the barometer was from a half inch to an entire inch lower than it was at the station of 2 inches rain-fall. Most of these eleven cases were therefore cases in which the influence of a low center was felt to an unusual distance. There were however two cases (Nos. 54 and 57) both on the same day, in which there was no considerable low center within a distance of 1000 miles, and these occurred in a region where a cyclonic movement of the winds of limited extent was formed between two centers of high pressure. We thus find that each of these cases of heavy rain occurred within an area where the barometer was depressed somewhat below its mean height, or where the barometer was relatively low when compared with neighboring areas of high pressure.

Within these areas of low pressure there was generally a cyclonic movement of the winds. This is indicated by the change in the direction of the winds shown in columns 9th and 10th. It will be seen that in eight cases the wind changed 180° in twenty-four hours; in seventeen cases the wind changed 135° in twenty-four hours; and in twenty-eight cases the wind changed 90° in twenty-four hours. There are, however, twelve cases in which no change in the direction of the wind was reported during these twenty-four hours, viz: Nos. 2, 4, 5, 8, 18, 20, 41, 60, 64, 66, 68 and 73. In eight of these cases the low center traveled very slowly, and the direction of the low center from the rain center changed but little in twenty-four hours; two of the remaining cases occurred on the summit of a mountain about which there is presumed to have been

Rain-fall of two inches in 24 hours.

No.	Date.	Station.	Lat.	Long. fr. Green.	Elev. feet.	Rain. inch's	Bar. red'd.	Wind. Prev. observ.	Wind. At date.	From low.
	1879.		° ′	° ′						
1	Jan. 2	Trieste, Austria	45 39	13 47 E	85	2·334	29·82	Calm	Calm	SE
2	4	Carlsruhe, Germ.	49 1	8 25 E	404	2·181	29 61	SW	SW	SW
3	6	Pic du Midi, France	42 16	0 8 E	7763	2·240	30·22	NNW	N	?
4	7	Pic du Midi, France	42 16	0 8 E	7763	2·212	30·07	N	N	?
5	10	Valona, Turkey	40 27	19 27 E	..	3·940	29·76	S	S	SE
6	30	Trieste, Austria	45 39	13 47 E	85	2·035	30·09	E	ENE	NE
7	Feb. 1	Nottingham, Eng.	52 57	1 10 W	174	2·770	30·08	ESE	SE	NE
8	9	Santiago, Spain	42 53	8 28 W	863	3·048	29 51	S	S	SE
9	10	Santiago, Spain	42 53	8 28 W	863	2·713	29·38	S	SW	SE
10	15	Trieste. Austria	45 39	13 47 E	85	2·063	29·51	Calm	E	NE
11	15	Monach, Hebrides	57 30	7 40 W	150	2·000	29·21	E	SSE	SE
12	15	Genoa, Italy	44 25	8 30 E	157	2·587	29·46	Calm	N	NE
13	17	Mont Louis, France	42 31	2 7 E	5203	2·917	29·71	SSW	WSW	S
14	Mar. 22	Genoa, Italy	44 25	8 30 E	157	2·657	29·58	Calm	S	E
15	23	Trieste, Austria	45 39	13 47 E	85	2·976	29·53	E	Calm	NE
16	26	Trieste, Austria	45 39	13 47 E	85	2·028	29·83	ENE	S	E
17	27	Trieste, Austria	45 39	13 47 E	85	3·511	29·63	S	E	SE
18	Apr. 3	Pic du Midi, France	42 16	0 8 E	7763	2·390	29·82	NW	NW	?
19	4	Pic du Midi, France	42 16	0 8 E	7763	2·469	29 95	NW	N	?
20	8	Nice, France	43 42	7 17 E	30	2·110	29·47	S	S	SE
21	8	Commune de Gr.	43 25	5 37 E	1056	2·252	29·47	SE	N	SE
22	16	Trieste, Austria	45 39	13 47 E	85	2·063	29·69	S	N	NE
23	21	Genoa, Italy	44 25	8 30 E	157	3·346	29·55	SW	NE	SE
24	22	Udine, Italy	46 4	13 14 E	380	2·252	29 70	S	SE	SE
25	29	Rome, Italy	41 54	12 29 E	207	2·598	29.69	W	N	SE
26	May 10	Puy de Dome, Fr.	45 46	2 58 E	4813	3·906	29·84	NW	NNW	SW
27	11	Cracow, Austria	50 4	20 0 E	721	2·467	29·68	ESE	NW	NW
28	20	Mondovi, Italy	44 22	7 48 E	1824	2·468	29·98	NNW	W	N
29	24	Moncalieri, Italy	44 59	7 41 E	853	2·098	29·91	SE	N	NE
30	26	Mondovi, Italy	44 22	7 48 E	1824	3·378	29·72	W	WNW	N
31	27	Mondovi, Italy	44 22	7 48 E	1824	2·091	29·69	WNW	N	SE
32	28	Szathmar, Austria	47 49	22 51 E	430	2·059	29·88	E	SW	SE
33	June 8	Santiago, Spain	42 53	8 28 W	863	2·241	29·82	SSW	W	SE
34	10	Eperies, Austria	48 58	21 15 E	820	2·045	29·90	SE	NW	SW
35	18	Hamburg, Germ.	53 33	9 58 E	66	3·366	29·62	SW	S	SE
36	July 2	Besançon, France	47 14	6 1 E	830	2·067	29·97	SW	SSW	SE
37	14	Nismes, France	43 51	4 21 E	187	2·760	29·95	S	N	SE
38	14	Geneva, Switz.	46 12	6 8 E	1339	2·551	29·90	NE	SW	SE
39	Aug. 3	Cambridge, Eng.	52 12	0 8 E	88	3·180	29·86	E	SE	NE
40	3	Cardington, Eng.	52 8	0 27 W	109	2·000	29·84	E	SE	NE
41	10	Besançon, France	47 14	6 1 E	830	2·421	30·08	S	S	?
42	17	Trieste. Austria	45 39	13 47 E	85	2·020	29·89	ESE	E	SE
43	17	Barcelona, Spain	41 23	2 11 E	98	2·908	29·99	SE	SSW	NE
44	18	Gratz, Austria	47 4	15 28 E	1171	3·544	29·86	NE	SE	SE
45	18	Hermannstadt, Aus	45 47	24 13 E	1355	2·150	29·71	WNW	WNW	SE
46	Sept. 2	Bergen, Norway	60 24	5 18 E	49	2·401	29 72	NW	S	NE
47	9	Christiania, Nor.	59 55	10 44 E	134	2·043	29·50	ENE	SSW	NE
48	10	Umea. Sweden	63 50	20 17 E	..	2·389	29·42	SE	N	NE
49	15	Carcassonne, Fr.	43 13	2 21 E	384	2·217	29·90	E	W	S
50	15	Commune de Gr.	43 25	5 37 E	1056	2 170	29·96	SW	SE	SE
51	15	Marseilles, France	43 18	5 23 E	246	3·051	29·88	SE	E	SE
52	16	Marseilles, France	43 18	5 23 E	246	6·261	29·91	E	ESE	SE
53	18	Pola, Austria	44 51	13 53 E	105	2·028	29·97	ESE	WNW	SE
54	25	Avignon, France	43 57	4 38 E	66	5·836	30 09	E	N	NW
55	25	Milan, Italy	45 28	9 11 E	482	2·599	29·99	NE	E	NE
56	25	Christiania, Nor.	59 55	10 44 E	134	3·083	29·86	SSE	SSW	SE
57	25	Zurich, Switz.	47 22	8 33 E	1542	2·047	30·21	S	W	NE

Rain-fall of two inches in 24 hours—continued.

No.	Date.	Station.	Lat.	Long. fr. Green.	Elev. feet.	Rain. inch's	Bar. red'd.	Wind. Prev. observ.	Wind. At date.	From low.
	1879.		° ′	° ′						
58	Sep. 26	Pola, Austria	44 51	13 53 E	105	3·962	29·85	SSE	WSW	NE
59	28	Nice, France	43 42	7 17 E	30	2·322	30·07	E	ESE	NW
60	Oct. 1	Santiago, Spain	42 53	8 28 W	863	2·091	30·03	SW	SW	SE
61	16	Brönö, Norway	65 30	12 0 E	36	2·087	29·80	NE	SW	NE
62	17	Cosenza, Italy	39 18	16 15 E	840	2·197	29·78	SE	NW	SW
63	18	Pola, Austria	44 51	13 53 E	105	2·008	29·85	WNW	SSW	SE
64	21	Carlsruhe, Germ.	49 1	8 25 E	404	2·020	29·79	SW	SW	SW
65	23	Valona, Turkey	40 27	19 27 E	..	2·360	29·88	SE	N	SW
66	28	San Fernando, Sp.	36 28	6 13 W	95	2·134	29·81	S	S	SE
67	29	Carcassonne, Fr.	43 13	2 21 E	384	2·106	29·85	ESE	E	NE
68	29	Perpignan, Fr.	42 42	2 54 E	98	2·102	29·86	SE	SE	NE
69	29	San Fernando, Sp.	36 28	6 13 W	95	3·183	29·78	S	SE	S
70	Nov. 1	Campo Major, Por.	39 2	6 59 W	945	2·296	29·79	ESE	SSW	E
71	2	Genoa, Italy	44 25	8 30 E	157	2·126	29·80	SW	S	NE
72	20	Genoa, Italy	44 25	8 30 E	157	3·165	29·88	NW	NE	NE
73	25	Helston, Eng.	50 5	5 17 W	..	2·400	30·32	E	E	NE
74	28	Santiago, Spain	42 53	8 28 W	863	2·024	29·30	NE	SSE	N
75	Dec. 4	Genoa, Italy	44 25	8 30 E	157	2·539	29·53	NE	N	SE
76	15	Bergen, Norway	60 24	5 18 E	49	2·500	30·29	SSE	SE	SE

a cyclonic movement of the winds nearly stationary as will be shown hereafter. In No. 2 there was a small barometric depression about 200 miles distant on the north side, and about this center there was a decided cyclonic movement of the winds. It seems probable that there was some change of wind at Carlsruhe during this period of twenty-four hours. In No. 41 the winds in France were light and a cyclonic movement of the winds was formed near Besançon resulting in a great rain-fall, but without any appreciable effect upon the barometer. We therefore conclude that each of these cases of great rain-fall (with perhaps one or two exceptions) occurred within an area of pressure somewhat below the mean, or at least a pressure relatively low, and that there was a cyclonic movement of the winds about this low center.

In order to show the position of these heavy rain-falls with respect to the centers of low pressure, I have prepared a chart of all these cases for 1879 similar to Plate I, which accompanied my seventeenth paper. Column 11th of the preceding table shows the quadrant in which each of these rain centers was situated, except that in a few cases the direction corresponded very nearly with one of the cardinal points, and this is indicated by the letters N, E, or S. There are also five cases marked with the character ? which will be considered hereafter. The following is a summary of the number of cases of great rain-falls for each of the four quadrants about the center of low pressure:

Northeast.	Southeast.	Southwest.	Northwest.
22	31	6	3

The three cases in which the great rain-fall took place on the N.W. side of the low center are Nos. 27, 54 and 59. May 11th there was a low center (29·37) about 200 miles southeast of Cracow, and during the preceding twenty-four hours the low center traveled only 275 miles, which is considerably less than the average velocity in this part of Europe for the month of May. Sept. 25th there was a high barometer (30·58) at Moscow, and another high (30·39) over Spain. Under the influence of these two areas of high pressure, a system of cyclonic winds was formed about the southeast part of France, resulting in a heavy rain-fall at various places in Switzerland and Northern Italy as well as at Avignon. This movement of the winds caused a considerable depression of the barometer (29 83) which was central over Northern Italy on Sept. 26th. Although the heaviest rain-fall may have occurred on the northwest side of this low center, very heavy rain also occurred on the northeast side of the low center. Sept. 28th there was a low center (29·80) southeast of Nice, and distant about 500 miles. During the preceding forty-eight hours, this low center traveled only 400 miles, or about eight miles per hour. Cases No. 27 and 59 appear to have been similar to that of Aug. 12, 1880, in Austria, where the principal rain-fall was on the west side of the low center and the low center remained nearly stationary for several days. It seems natural to conclude that the low center remained stationary *because* the principal rain-fall was on its west side.

The six cases in which the great rain-fall took place on the S.W. side of the low center are Nos. 2, 26, 34, 62, 64 and 65. Jan. 4th Carlsruhe was situated on the S.W. side of a low center (29 13 inches) at a distance of nearly 1000 miles; but on the 3d of January there was a decided cyclonic movement of the winds about the southern portion of the North Sea, accompanied by a slight depression of the barometer on the northwestern side of Carlsruhe, and the great rain-fall at Carlsruhe was probably the result of this local movement rather than the effect of that distant area of low pressure on the northeast side. No. 26, May 10th, was similar to the preceding case. A cyclonic movement of the winds covering nearly the whole of France was very decided, although the principal center of low pressure was distant 800 miles on the east side. No. 34, June 10th, was also similar to the preceding, the wind at Eperies having been S.E. June 9th and N.W. June 10th. No. 62, Oct. 17th, presents another similar case. The wind at Cosenza was S.E. on the 16th and N.W. on the 17th. In No. 64, Oct. 21st, rain was very general throughout nearly the whole of Europe, and it apparently resulted not so much from the existence of an area of low pressure over the Baltic Sea,

as from local cyclonic winds prevailing over Northern Italy and Austria, although the observations do not show any such system of winds near Carlsruhe. In these five cases the great rain-fall occurred at a distance of from 600 to 800 miles from the center of the low area in which it was included. In my seventeenth paper I have shown that in the United States, when a heavy rain-fall occurs at a distance of more than 500 miles south of a low center, the rain fall has apparently very little influence upon the direction in which the low center advances, or upon its rate of progress. A similar remark is applicable to Europe. In these five cases the rain-fall appeared to have very little influence upon the center of the principal low area in which the rain center was situated; but in four of the cases a subordinate low center was formed near the rain area. In the other case (No. 34) the local effect uopn the barometer was not distinctly marked. In No. 65, Oct. 23d, the low center was about 100 miles N.E. of Valona. On the 22d the wind was S.E. and 1·30 inch of rain was reported; on the 23d the wind was north and 2·36 inches of rain were reported. The observations do not clearly show whether this rain fell chiefly before or after the change of wind.

Of the five cases in the table which are marked with an ? in column 11th, four occurred on the Pic du Midi. In each of these cases there were indications of a cyclonic movement of the winds around the Pyrenees. This is seen by comparing the direction of the winds at the nearest stations of observation on different sides of the mountains. The following table shows the four cases of 1879 and also all the cases in 1878 and 1880, in which the precipitation at this place amounted to two inches of water in twenty-four hours.

No.	Date.	Bilbao.	Tarbes.	Pic du Midi.	Toulouse.	Mont Louis.	Carcassonne.	Perpignan.	Barcelona.
1	1879. Jan. 6	NW	W	N	NW	NW	NW	NE	E
2	Jan. 7	NW	SSW	N	W	WNW	NE	E	E
3	April 3	NW	W	NW	W	W	W	NE	SE
4	April 4	NW	W	N	NW	NW	W	N	S
5	1878. Mar. 25	NW	WSW	NW	WNW	WSW	W	NW	NE
6	Dec. 2	NW	..	NNE	WNW	SW	E	N	WNW
7	1880. April 3	SW	NW	S	W	WSW	W	NE	S
8	April 27	NW	W	NNE	N	WNW	WNW	NW	E
9	May 6	NW	W	NE	SE	WNW	E	NW	S
10	May 7	NW	W	W	NNW	W	W	NW	SSW
11	Sept. 20	NW	W	W	NW	WSW	W	NE	SSE

In 1880, the direction of the wind on the Pic du Midi was not reported, and the winds shown for that station in 1880 are the directions of the lower clouds. At Mont Louis the lower clouds were reported from S. in case 1; from S.E. in case

6; from E. in case 8, and from E. in case 10. At Carcassonne the lower clouds were reported from E. in case 2. In most of these cases the evidence of a cyclonic movement of the winds is very distinct. The observations at Barcelona indicate a cyclonic movement about the eastern portion of the Pyrenees in nine of the cases; the observations at Perpignan indicate such a movement in five of the cases; the observations at Carcassonne indicate such a movement in three of the cases; the observations of the clouds at Mont Louis indicate such a movement in four of the cases; and the observations on the Pic du Midi indicate such a movement in four of the cases. For the eleven cases we may conclude that in eight of them the cyclonic motion of the winds is distinctly marked; while in three of them the evidence is not entirely clear. No. 41 occurred where the barometer was near its normal height and was situated between two areas of low pressure. A local circuit was formed near Besançon, resulting in a great rain-fall, but without any appreciable effect upon the barometer.

Cyclonic movement of the winds about Trieste.

No.	Date.	Moncalieri.	Mondovi.	Milan.	Florence.	Padua.	Pesaro.	Udine.	Trieste.	Pola.	Gratz.	Agram.	Kremsmünster.
	1879.												
1	Jan. 2	ESE	NE	W	SW	NW	S	Calm	Calm	S	WNW	NW	WNW
2	30	ENE	NW	SSE	W	NE	N	SE	ENE	ENE	SSE	E	ENE
3	Feb. 15	NNW	WSW	NNE	SE	NE	SE	NE	E	SE	WSW	E	NE
4	Mar. 23	W	NW	SE	E	NE	N	SE	Calm	SE	SW	SE	E
5	26	E	W	ESE	SE	NNE	E	E	S	SE	S	E	ENE
6	27	SSE	NNW	S	NW	NNE	NW	E	E	W	E	E	ENE
7	April 16	ENE	SW	E	E	N	N	SW	N	SE	WSW	SW	NE
8	Aug. 17	WSW	NW	ESE	S	SE	SE	SE	E	S	NE	SW	W
	1878.												
9	April 24	NNW	SW	NE	SE	NNE	E	E	ENE	SE	SW	SE	SE
10	May 8	W	NW	E	WSW	SW	W	S	SW	SSW	NW	SW	W
11	25	SSE	NE	NE	SW	ENE	SE	S	SE	SE	SW	SW	WNW
12	June 5	SSE	N	SW	W	E	SW	SE	Calm	SSE	SSW	NE	W
13	15	SSW	ENE	N	SW	SE	S	SW	E	S	ESE	NE	WSW
14	July 26	SSW	NW	--	WSW	NNE	NE	N	ESE	Calm	E	NW	W
15	30	NE	NE	--	W	SE	E	Calm	NW	SE	NE	NE	W
16	Sept. 15	SW	NW	SE	SE	ENE	W	Calm	Calm	NE	E	NE	Calm
17	20	NW	N	ESE	NW	SE	NE	--	W	SE	SW	NE	Calm
18	24	NNW	NW	E	E	NE	--	E	SSE	SE	S	NE	W
19	Oct. 9	SE	N	E	ENE	E	--	E	Calm	SSE	E	NE	Calm
20	14	SSE	W	W	WNW	ENE	NW	NE	ENE	ENE	ENE	NE	ENE
21	21	NNW	NW	ENE	SE	N	E	Calm	Calm	S	S	SW	ENE
22	Nov. 14	NE	SE	W	SW	S	NW	N	SW	SSE	NE	NE	W
23	Dec. 17	ENE	Calm	NE	N	N	W	NE	Calm	SSE	S	SW	Calm
	1880.												
24	July 31	NNW	WNW	S	S	NNW	NE	SW	N	SE	S	NE	WSW
25	Sept. 20	ENE	NE	ESE	SSE	E	S	SW	SW	SSW	SE	NE	WNW
26	Dec. 18	N	WNW	N	ENE	N	S	SW	Calm	SSE	SSW	E	ESE

In nearly all of the other cases in the table, the evidence of a cyclonic movement of the winds about the rain center is equally clear. In order to give a more distinct idea of the nature of the evidence, I subjoin the preceding table showing the direction of the winds at a few of the stations near Trieste at the time of the rain-fall of two inches at the latter place. The table shows all the cases which occurred at this station during the three years 1878, 1879 and 1880.

In nearly all of these cases the evidence of a cyclonic movement of the winds about a center not far from Trieste is unequivocal. The cases which appear most doubtful are Nos. 1 and 10. In No. 1 we find south winds at Pesaro and Pola opposed by northwest winds at Padua and Agram, which affords pretty good evidence of a cyclonic movement. In the case of No. 10 the low center was on the east side of the stations shown in the table; but at several stations farther east, the winds blew from an eastern quarter.

The preceding discussion appears to me to warrant the following conclusions.

1. Cases of very heavy rain-fall in Europe almost invariably occur within or near an area of low pressure, but a great rain-fall is frequently due to a local cyclone of moderate extent formed within or near a large area of low pressure. This remark applies not merely to those cases in the table in which the rain-center was on the west side of the center of low pressure, but also to many of the cases in which it was on the east side. Whenever the movement of the winds about a center of low pressure is feeble, there frequently results a local disturbance attended by a cyclonic motion of the winds and a considerable precipitation of vapor; and this is generally associated with a subordinate area of low pressure which sometimes extends and attains considerable magnitude. In many cases, this precipitation of vapor appears to be due to the influence of mountains by which the air when set in motion is deflected upward.

2. These rain-falls most frequently occur on the east side of an area of low pressure. In 1879, the cases in which a heavy rain-fall occurred on the east side of a low center, were nearly six times as numerous as those on the west side; and even if we count all those cases marked N or S, as having occurred on the west side of the low center, we shall still find the cases on the east side to be nearly four times as numerous as those on the west side.

3. Nearly four-fifths of the cases enumerated in the table on page 12 occurred at stations south of lat. 48°, so that the conclusions above stated apply primarily to southern Europe, and we cannot fail to notice a marked correspondence between the

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effects of a heavy rain-fall in southern Europe, and in the southern part of the United States. In both countries the influence of a great rain-fall upon a center of low pressure is generally not very decidedly marked; while in the northern part of the United States, this influence is generally quite obvious and decided. In the United States, the parallel of 36° generally forms a satisfactory dividing line between these two classes of cases; but in Europe this dividing line is found in a much higher latitude, perhaps near the parallel of 48°. I have made an extensive collection of cases of heavy rain in Europe, north of this parallel, and have found a close correspondence with cases of heavy rain in the United States, north of the parallel of 36°. For the year 1880, in northern Europe (employing all cases in which the rain-fall amounted to as much as one inch in 24 hours), the rain-center occurred on the east side of the center of low pressure more than four times as frequently as it did on the west side; the rain-center was found in the northeast quadrant as frequently as in the southeast quadrant; the cases of one inch rain-fall in the northwest quadrant were only three in number, and in neither of these cases was the rain-center distant from the center of low pressure more than 150 miles. For all the cases in 1880 in northern Europe, the average distance of the rain-center from the center of low pressure was 420 miles, and the average pressure at the center was 740 millimeters or 29·13 inches.

ART. II.—*On Bowlder Drift in Delaware;* by F. D. CHESTER.

ABOUT two miles to the south of Newark, Delaware, on the line of the Baltimore & Philadelphia Railroad, there rise above the level of the plain two hills, which, uniting with each other, trend in a nearly east and west direction. Their total length is about two miles, their breadth one mile, and their height between two and three hundred feet.

These hills present material for interesting geological observations from two principal reasons. In the first place, like most hills of this size they are not made up of rocky strata, but from base to summit the forming material is an irregular mixture of sand, gravel and bowlders. The subject has further interest because this material, which is clearly of true drift origin, is found so far to the south, and below the southern limit, of the glacial field.

From Newark to Wilmington, running across the northern part of Delaware, is a chain of hills made up of the highly tilted gneissic rocks; this chain marks the southern boundary

of the Archæan rocks of the State. Resting unconformably upon these latter are strata of red, white and yellow clays of Cretaceous age, dipping at so low an angle to the southeast, that they seem almost horizontal. The position of these clay deposits gives to the country south of Newark a very even topography, hence when we see these two hills of detritus rising above the plain they become objects peculiarly conspicuous and interesting.

At the very foot of the hills we find the material a ferruginous sand, mixed with quartzose pebbles and fragments of compact iron-stone. Wherever we can get cuttings in this loose earth, no apparent signs of stratification can be observed; on the contrary we see only a confused mixture. As we reach the top we find excellent cuttings made where iron ore is worked in open quarry. The side of the hill near one of these workings has scattered over its surface large bowlders of iron-stone, ferruginous quartz and dolerite. In one of the cuttings the bank rises to a height of thirty feet. The main material is the same red sand and gravel, slightly argillaceous. No signs of stratification can be observed anywhere, but irregularly disseminated throughout the earth are fragments and bowlders of various materials, the most conspicuous being the immense bowlders of iron-stone. Among the other materials noticed in this confused mixture were fragments of green talcose slate, decomposed soapstone, kaolin and bowlders of compact dolerite. One immense slab of light green talcose slate was found embedded in the earth, which upon measurement I found to be fifty feet around.

In another cutting the banks of ferruginous sand and gravel rise between thirty-five and forty feet, with no signs of stratification, but with the materials scattered through the earth in irregular patches, bowlders and fragments. These former, so characteristic of this cutting, are made up of red and white decomposed materials, derived from the decay of a red orthoclase granite in one case and in the other of a black micaceous gneiss. The white patches are by far the largest and most numerous, one of which presented a face thirty feet high, and fifty feet long. Facts clearly point to the belief that the rocks whence the granitic materials came were brought to their present position in a solid state, and that the decomposition was subsequent, for it is found that in the white there is still the distinct schistose structure of the original rock, while the red retains its true granitic characters. The chief interest connected with these facts is that the rocks whence these loose materials came must have been immense in size, as well as numerous, and that they were once scattered through the earth like the equally large bowlders of ferruginous quartz and iron-stone.

Some of these latter are enormous in size. One bowlder of highly ferruginous quartz was found to measure forty-one feet in circumference: another of nearly equal size and of the same material was seen resting like a rocking stone upon a smaller one beneath, the earth having been removed from around it. Besides these larger examples, the whole bank is completely filled with bowlders of iron-stone, large and small, distributed irregularly throughout the confused mass, and it is this fact which gives the deposits their economic importance.

One of the most interesting facts with regard to the geology of these hills is the occurrence of great bowlders of dolerite which are thickly strewn over every part and even in the meadow land to the north, and just at the foot of the hills the ground is so covered with them, that one is immediately reminded of similar scenes in more northern latitudes. At the very beginning of the ascent I came across the largest bowlder of dolerite yet found; it measured thirty-seven feet in circumference, and another near by, sixteen. At the top, the west side of one of the hills was so literally strewn with bowlders that one could not step without walking on them: one of these measured twenty-five feet in circumference and numerous others were not less than fifteen, all the remainder varying from this size down.

I have to note here that I have found bowlders both to the north and ten miles to the south of these hills, some of them varying in size from fifteen to twenty feet in circumference.

In all these cases of bowlder examination, I have not succeeded in discovering distinct glacial scratches, although patient search was kept up. In a few instances parallel striæ were seen, but these were so obscured by the extreme weathering of bowlders that their true nature remains a question of doubt.

In almost every case the surfaces of the rocks were either so weather-worn or moss-covered as to obscure all evidence with regard to this point, and their presence or absence must remain an uncertain question. As to the explanation how bowlder drift could have been brought to this remote locality, there is much which is interesting. It is a well-known fact to all geologists, that bowlders have been found as far south as the Southern States, and that their presence in these localities is explained by supposing that they were transported by floating icebergs which found their way to the south at the close of the Glacial period; hence it seems to be the most probable theory, that not only the solitary bowlders found in Delaware, but that the materials of these two hills were transported southward by floating ice during the Champlain period.

The entire want of stratification observed in both hills would tend to show that the materials were dropped pell-mell from

the melting ice-floats, while the slightly stratified arrangement of the sand and gravel for not more than a foot in the topmost layer of the cuttings would show a slightly modifying effect of the waters into which the debris was dropped. It was only in two localities that this stratification of the surface could be observed, while such regular arrangement was by no means true of all parts of the uppermost material.

Professor G. H. Cook (Ann. Rept. of N. J., 1880, p. 94) mentions the occurrence of bowlders in Cape May County, New Jersey, near the town of Dennisville. He gives the dimensions of the largest one found in that part of the State as fourteen feet, and its other dimensions eleven to seventeen inches, by thirteen to sixteen inches. These figures may make some readers skeptical as to those already given, yet their accuracy may in this case be depended upon, since the bowlders were accurately measured by myself.

Professor Cook attributes the presence of bowlders in Cape May County to ice-flows coming down the Delaware, when the land was submerged to the depth of at least sixty feet during the Champlain period.

It is hardly probable that Professor Cook's explanation will apply to the case of the two hills or the bowlders of Delaware, from the fact that the base of these hills is not less than eighty feet above the Delaware river, and, adding to this 228 feet, the height of one of the hills, and considering the further fact that a few of the largest bowlders are found at the very summit, we have the occurrence of these rocks 308 feet above the level of the river. There is again the further consideration that while the bowlders about Dennisville occur upon the alluvial land bordering the Delaware, and upon land no doubt the work of this stream, those of Delaware are found from ten to twelve miles from the river, and with different geological surroundings. The tracing also of sand and gravel, similar in character to that found in the hills, for some distance due north, would also seem to indicate that the floating ice was not alone confined to even the ancient channel of the Delaware River.

Whether the great height of these hills above the level of the Delaware would not seem to indicate a greater submergence of the land during the Champlain period than is reckoned for this locality, will be a question worthy of consideration, provided future evidence shall strengthen the theory.

Delaware College, Newark, Delaware, Dec. 8, 1882.

ART. III. — *Upon the Electrical Experiments to determine the location of the Bullet in the body of the late President Garfield: and upon a successful form of Induction Balance for the painless detection of Metallic Masses in the Human Body*;* by ALEXANDER GRAHAM BELL.

(A paper read before the American Association for the Advancement of Science, at the Montreal meeting, August, 1882.)

THE subject of my present paper recalls a time of intense excitement and painful suspense. The long, weary struggle with the untimely death-wound—the prolonged suffering borne so bravely and well by the lamented President Garfield—must still be fresh in every recollection. The whole world watched by his bed-side, and hopes and fears filled every passing hour. No one could venture to predict the end so long as the position of the bullet remained unknown. The bullet might become safely encysted, but, on the other hand, recovery might depend upon its extraction. The search with knife and probe among vital and sensitive tissues could not be otherwise than painful and dangerous; and the thought naturally arose that science should be able to discover some less barbarous method of exploration.

Among other ideas the thought occurred that the bullet might produce some sensible effect in modifying the field of induction of a coil brought near the body of the President, and that the locality of the bullet might thus be determined without danger to the patient and without pain; for it is well known that induction can be powerfully exerted through the human body without producing any sensation whatever.

Upon the balancing of Induction.—The influence that is exercised upon induction by metallic masses has formed the subject of numerous experiments by different investigators; and the principle of balancing the effects of induction on one portion of a circuit by equal and opposite effects produced upon another portion has been utilized in nearly all such investigations.

The earliest form of induction balance for this purpose appears to have been devised in Germany by Prof. Dove,† about the year 1841, and a good description of it in the English language may be found in De la Rive's "Treatise on Electricity," (1853 edition, vol. i, pp. 418–433).‡

* A preliminary notice relating to this paper was published in the Comptes Rendus of the French Academy of Sciences, Oct. 24th, 1881.

† Pogg. Ann., vol. liv, pp. 305–335.

‡ A similar apparatus was independently devised in America a number of years ago by Prof. Rowland, of the Johns Hopkins University. It is to be regretted that his discovery of the fact that he had been anticipated by Dove prevented Prof. Rowland from completing and publishing his researches.

Another and superior arrangement for the same purpose is the well-known induction balance of Prof. D. E. Hughes.*

The Static Induction Balance of J. E. H. Gordon† though primarily intended for experiments upon specific inductive capacity, might also, perhaps, be employed in the same class of investigations.

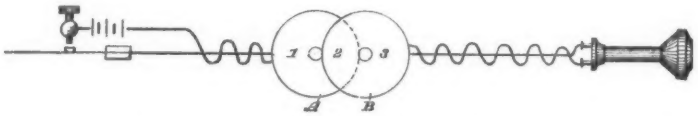
My own attention was directed to the balancing of induction a number of years ago by the disturbing noises produced in the telephone by the operation of telegraphic instruments upon lines running near the telephone conductor.

The difficulty was remedied by using two conductors instead of one, and by so arranging them with reference to the disturbing wires that the currents induced in one of the telephone conductors were exactly equal and opposite to those induced in the other. In this way an induction balance was produced and a quiet circuit secured for telephonic purposes. This method was patented in England in November, 1877, and during the whole winter of 1877–8 I was engaged in London upon experiments relating to the subject.

In the course of these researches I made frequent use of flat spirals of insulated wire, like those employed by the late Prof. Henry‡ in his experiments upon induction.

My method was to pass a rapidly interrupted voltaic current through one flat spiral while I examined its field of induction by means of another flat spiral connected with a telephone. The currents induced in the latter coil produced a musical tone from the telephone.

Fig. 1.



At every point in the field of induction it was found that by turning the plane of the exploring coil a position of silence could be obtained, and another of maximum sound, the two positions making a right angle with one another.

It was also noticed that when a position of silence was established a piece of metal brought within the field of induction caused the telephone to sound. This effect was most marked when the two flat spirals were in close proximity, and were arranged with their planes parallel, as shown in fig. 1.

When a silver coin, such as a half-crown or florin was passed across the face of the two coils, the silence of the telephone was broken three times. The instrument emitted a musical

* Phil. Mag., July, 1879, vol. ii, p. 50. † Phil. Trans. for 1879, p. 417.
‡ This Journal, xxviii, 329; xxxviii, 209; xli, 117.

tone when the metallic disk passed the points marked 1, 2 and 3 in the illustration, but the loudest effect was produced when the coin crossed the area marked "2," where the two coils overlapped.

After my return to America I embodied these and other results in a paper "Upon New Methods of Exploring the Field of Induction of Flat Spirals," which was read before this Association at the Saratoga meeting in August, 1879.

Practical application.—While brooding over the problem of the detection of the bullet in the body of President Garfield, these experiments made in England returned vividly to my mind. It seemed to me that if the overlapping area "2" of the two coils shown in fig. 1 could be brought over the seat of the bullet without disturbing the relative positions of the coils, the telephone would probably announce the presence of the bullet by an audible sound.

A crude experiment was at once made to test the idea. A large, single-pole electro-magnet (the core of which was composed of a bundle of fine iron wires) was used in place of coil A (fig. 1); and a small coil of fine wire taken from a hand telephone was arranged a little to one side of the pole to represent coil B. The small coil being connected with a telephone, a battery current was passed through the coil of the electro-magnet, and the battery circuit was made and broken by an assistant.

Under these circumstances a much better balance was obtained than could possibly have been anticipated. Upon now bringing a leaden bullet near the small coil, a distinct ticking sound could be heard from the telephone each time the battery circuit was made and broken.

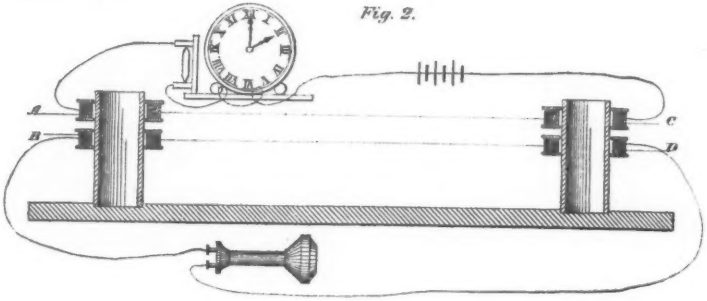
Being absent from my laboratory, and without facilities for proper experiment, I communicated my ideas to Mr. Charles Williams, Jr., of Boston, manufacturer of electrical and telephonic apparatus, who kindly placed the resources of his large establishment at my service; and, at great personal inconvenience, delegated his best workmen to attend to my experiments.

Upon attempting to devise an appropriate form of apparatus for the special purpose in view I saw that there were great practical difficulties in the way of utilizing the arrangement shown in fig. 1, and it occurred to me that the apparatus of Prof. Hughes might perhaps be employed with more advantage as the basis of my experiments. In the ordinary form of Hughes' induction balance four coils are used, as shown in fig. 2. Through the agency of a Hughes microphone the ticking of a clock is made to create an electrical disturbance in the voltaic circuit containing the two primary coils (A C) and a

corresponding disturbance is produced by induction in the two secondary coils (B D) connected with the telephone. If the connections are so arranged that the currents induced in the telephone circuit by the coils A C are in the same direction, the ticking of the clock is heard very plainly, but if they are in opposite directions no sound is perceived.

In the latter case the action of one primary coil (A) opposes that of the other (C), and an electrical balance results. If now a piece of metal is brought near one pair of coils (say A B) the balance is disturbed and the ticking of the clock is audible at the telephone. The arrangement of the coils (A, B, C, D) was the point to be studied, the microphone attachment being of no importance in the combination ; for it is well known that a rheotome to break the primary circuit completely at intervals can be substituted for the microphone with advantage.

Fig. 2.



It seemed to me that two of the coils (A B) in the Hughes induction balance might be attached rigidly to a wooden handle, so as to be moved over the seat of the bullet without changing their relative positions, and that all the adjustments necessary might be made on the other pair of coils, which need not be moved from their place, and would not therefore be liable to disarrangement. If a single pair of coils were to be used as in fig. 1, they must be adjustable one upon the other. But if during the course of exploration the coil B (fig. 1) should be moved from its proper position even to the extent only of a small fraction of a millimeter, the balance would be disturbed and the exploration might have to be stopped in order to adjust the apparatus. These considerations led me to the conclusion that some modification of the Hughes induction balance was most suitable for my purpose, and I immediately commenced the construction of such an apparatus.

Suggestions tested.—Just at this time I learned from the newspapers that Prof. Simon Newcomb, of Washington, had the

idea of using a magnetic needle to indicate by retardation of its rotation the proximity of the bullet in the body of the President, and I telegraphed to Prof. Newcomb the offer of my assistance in carrying on experiments, knowing the comparative difficulty he would experience in having apparatus made in Washington.

At his suggestion I tested the point whether the rotation of a leaden disk and of a leaden bullet underneath a delicately suspended magnetic needle would cause a deflection of the needle.

The disk occasioned a deflection, but the bullet produced no sensible effect. I telegraphed the result to Prof. Newcomb, and at the same time took occasion to inform him of the hopeful results I had obtained with the crudely constructed induction balance referred to above.

I was much gratified by his immediate appreciation of the experiment. He telegraphed that he thought an induction balance promised a much more hopeful solution of the problem than his own method, and encouraged me in every way to continue my experiments.

This appreciation determined me to proceed to my laboratory at Washington, where I was accompanied by Mr. Sumner Tainter, who was anxious to assist in such a cause. I learned from Prof. Newcomb that Mr. Geo. M. Hopkins, of Brooklyn, had independently suggested the use of Hughes' induction balance, and had made experiments in Brooklyn, the results of which were published in the New York Tribune on the 11th of July, 1881. Mr. J. Stanley Brown (private secretary of President Garfield) kindly handed to me the letters he had received from Mr. Hopkins, and also a Hughes' induction balance like that shown in fig. 2, which Mr. Hopkins had forwarded to the Executive Mansion for trial.

This apparatus was at once tested in my laboratory, with results slightly better than those I had obtained in Boston.

My Boston apparatus did not give a greater hearing distance than 3 cm., whereas with the Hopkins apparatus I could distinguish effects at a distance of 3.75 cm.

Two of Mr. Hopkins' coils (A B, fig. 2) were then fastened upon a wooden handle to form an exploring instrument, and the whole apparatus was arranged for immediate use in case of any necessity arising for an experiment upon the President. I set myself in communication with Mr. Hopkins, and requested his assistance and coöperation, and in reply received through Private Secretary Brown the following account of further experiments:

"60 Irving Place, Brooklyn, July 16, 1881.

"Mr. J. Stanley Brown:

"Dear Sir: I have made two new instruments on plans differing from that sent, but they yield no better results. The first consisted of two oblong coils arranged at right angles to each other, thus:

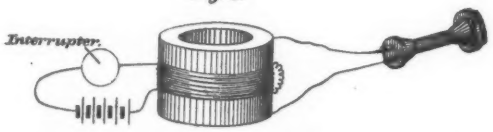
Fig. 3.

"The outer coil being of coarse wire (No. 18) placed in the primary circuit, the inner coil being of very fine wire (No. 36) and connected with a telephone. The parallel currents traversing the wires neutralized each other, and no audible effects are perceived in the telephone, but on presenting a metallic body to the instrument upon a line bisecting the angle between the coils the clicking in the telephone is heard.

"This instrument possesses only one advantage over that sent, and that is that it requires no adjustment.

"The other instrument consists of two large coils of very fine wire (No. 36) placed upon opposite sides of a coil of coarse wire (No. 16), the fine coil being connected so that the induced currents neutralize each other, thus:

Fig. 4.



"I am sorry to be obliged to say of this as of the other, that it is no more sensitive than the one sent. To produce the best effects from the instrument which you have it will be necessary to use all the battery power possible without burning the coils, and two receiving telephones of the best construction must be used.

"As I stated in the first instance, if the ball is more than two inches deep, I think it cannot be located by this means.

"If larger coils were used the instrument might be operative at a greater distance, but the area indicated as containing the ball would be so large that the result would be indefinite and without value.

"Hoping that Prof. Bell will be able to succeed, I remain,

"Yours very truly,

"Geo. M. Hopkins."

Prof. Hughes of London, England, Prof. Trowbridge of Harvard College, Prof. Rowland of Johns Hopkins University, and other authorities were consulted by telegraph as to the best theoretical form of induction balance for the purpose required, while empirical experiments were being carried on under my direction in my laboratory at Washington by Mr. Sumner Tainter; in the electrical work-shop of Davis and Watts, in Baltimore, by Mr. J. H. C. Watts, and in the establishment of Mr. Chas. Williams, Jr., in Boston, by Mr. Thomas A. Gleason. To test the influence of size of coil, an instrument was constructed in which the coils were no larger than the bullet for which we sought (as had been suggested by Prof. Newcomb), and experiments were also made with the enormous coils used by the late Prof. Henry in his researches upon induction, which were kindly lent to me for the purpose by the Smithsonian Institution, but neither the small nor the large coils produced more satisfactory results than those we had already obtained.

To test battery power, 20 enormous Bunsen elements, which had formerly been used to light the gas at the Capitol, were placed at my disposal by Mr. Rogers, electrician of the Capitol, but while great electro-motive force was evidently of use we derived no advantage from such a battery as this.

To test the influence of speed of interruption, Mr. Marean, Supt. of the Western Union Telegraph Co. in Washington, kindly lent us an electric motor, by means of which we were able, with the aid of a rotating commutator, to obtain interruptions of the primary circuit of all rates up to 600 interruptions per second,* and we found that the more rapid the rate of interruption the more distinct was the sound in the telephone. The hearing distance, however, was not proportionately increased. The automatic interrupter (shown in fig. 5), yielding about 100 interruptions per second, gave as good results as any, and was much more convenient. This interrupter was therefore afterwards used exclusively in our experiments.

The theoretical form o coil suggested by Prof. John Trowbridge was substantially the same as that proposed by Prof. Rowland, and is shown in fig. 6.

The arrangement was quite sensitive to metal placed in the interior of the coil, but the hearing distance for a bullet external to the coils was no greater than before.†

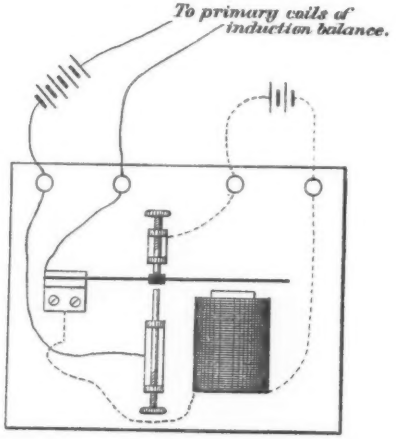
Professor Hughes proposed to have two flat superposed coils wound on a single reel, so that the two coils should form

* Mr. Sumner Tainter has since made an apparatus operating in a similar manner by means of which he has obtained as many as 4,000 interruptions of the circuit per second.

† The balance obtained was not quite perfect, and we have since discovered that the insulation of the wires of one of the secondary coils was defective.

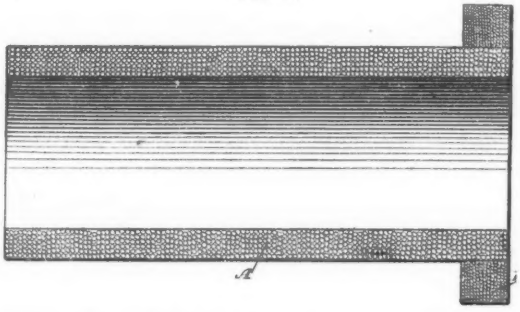
a single one as regards their relative distance; and Mr. F. T. Bickford, Washington correspondent of the New York Tribune, suggested winding two wires side by side into a single coil, so that the relative distances of the wires from the bullet should

Fig. 5.



be absolutely the same. Mr. Charles E. Buell and Dr. Chichester A. Bell proposed to determine the depth of the bullet beneath the surface by causing a similar bullet to approach the balancing coils until silence was restored; the secondary bullet

Fig. 7.



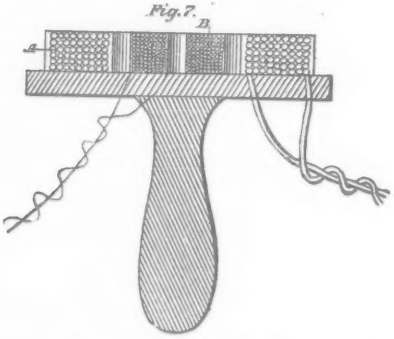
it was presumed would then be at the same distance from the balancing coils as the embedded bullet from the exploring coils.

The results of all the experiments so far made were unsatisfactory. I had tried every thing that had been suggested, but 4^{cm} remained the extreme limit of audibility for a bullet like

that which had struck the President. Even when such a bullet was flattened by being fired against a board, and was presented with its flat side toward the coils of the explorer—the most favorable mode of presentation—no better result was obtained.

Original Experiments.—In the theoretical arrangement recommended by Professors Trowbridge and Rowland (fig. 6) the primary coil A was of smaller diameter than the secondary B. This had given us no better effects than the ordinary form of Hughes' balance (see fig. 2), in which the two coils A B were of equal diameter. We then tried the effect of making the primary coil A of greater diameter than the secondary B (see fig. 7), and in this case we appeared to obtain an increase of

Fig. 7.



hearing distance. Five centimeters (2 inches) was, however, the utmost limit reached, when, on the 19th of July, Mr. J. Stanley Brown and Dr. Woodward visited my laboratory and witnessed some experiments. No difficulty was experienced in detecting a bullet held in the mouth by passing the exploring coil over the cheek; and the presence of a flattened bullet held in the clenched hand was also readily determined. Dr. Bliss, Dr. Reyburn and Surgeon-General Barnes visited the laboratory next day and expressed themselves as very hopefully impressed by the experiments. These were subsequently repeated in the surgeon's room at the Executive Mansion, for the information of Dr. Frank Hamilton and Dr. Agnew, who also seemed favorably impressed.

Such opinions from the surgeons in attendance upon the President, and the continued interest shown by Professor Newcomb, encouraged me to proceed with the experiments.*

It was now determined to test the effect of each convolution of the primary coil, so as to arrive empirically at some idea of

*I desire specially to express my gratitude to Dr. Frank Hamilton for words of encouragement spoken at a later date when sympathy and encouragement were greatly needed.

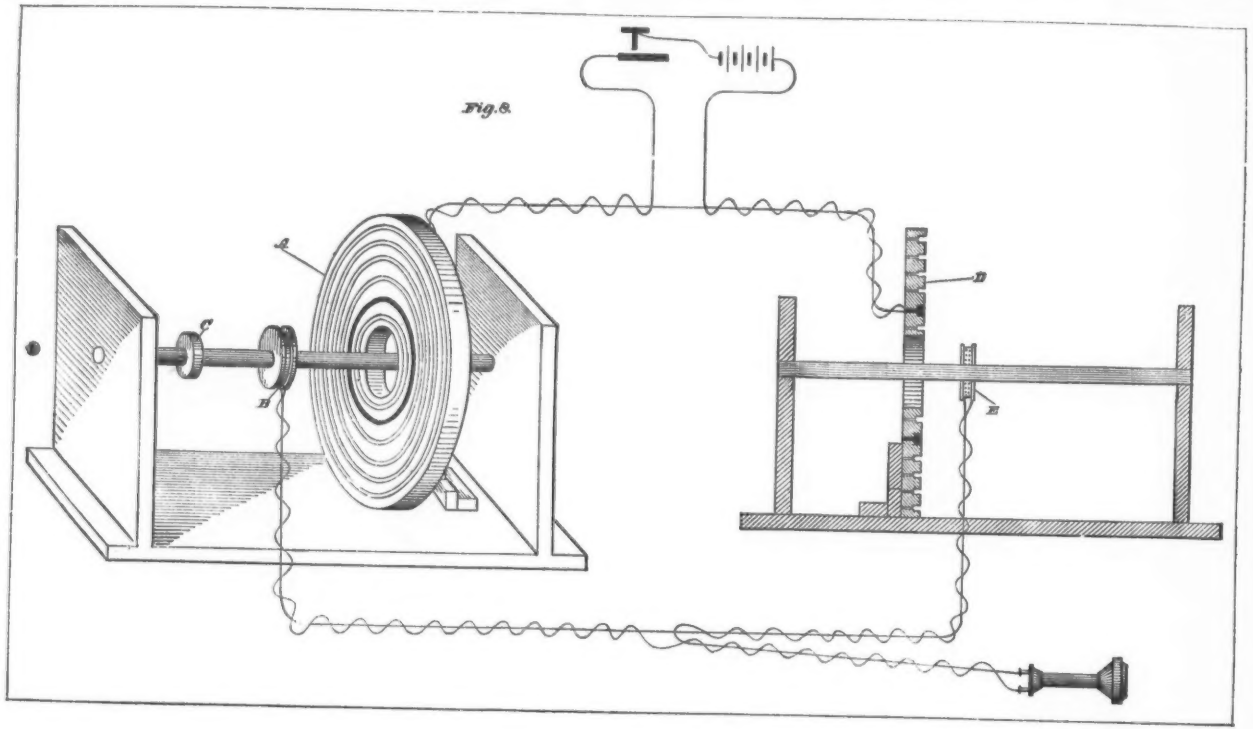


Fig.8.
A
C
B
D
E

the best shape of coil. For this purpose Mr. Tainter constructed the instruments shown in fig. 8. Circular grooves were turned in two boards, one of which is shown in perspective at A and the other in section at D. An insulated copper wire could be pressed into any of these grooves, so as to give the wire an exactly circular shape of known diameter, and the two ends were passed through an orifice in the back of the board, making connection with a similar ring of wire in the other instrument as shown. A small secondary coil (B) of fine wire, which could be moved with moderate friction upon the horizontal rod, was connected to another similar coil (E), and to a telephone; and a small brass ring (C), which could also be moved along the horizontal rod, was used instead of a bullet to disturb the balance.

In making an experiment with this apparatus the secondary coil (B) was first placed within the primary ring and in the same plane with it, and the balancing coil E was adjusted to produce silence. The brass ring C was then moved along the horizontal rod until the balance was sensibly disturbed and the relative distances of the coils and the brass ring were noted.

RESULTS OF A SERIES OF EXPERIMENTS MADE ON THE 19TH OF JULY, 1881.

Diameter of Primary Ring.	Distance between—			Diameter of Primary Ring.	Distance between—		
	A B	B C	A C		A B	B C	A C
mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
	0	17	17		0	27	27
	5	14	19		5	20	25
30	10	13	23	159	10	18	28
	20	9	29		20	17	37
	30	7	37		30	14	44
	50	0	50		50	14	64
	0	17	17		0	12	12
	5	19	24		5	18	23
50	10	26	36	206	10	25	35
	20	17	37		20	19	39
	30	14	44		30	22	52
	50	5	55		50	18	68
	0	21	21		0	20	20
	5	23	28		5	18	23
81	10	23	33	253	10	20	30
	20	18	38		20	19	39
	30	14	44		30	23	53
	50	12	62		50	20	70
	0	22	22				
	5	25	30				
113	10	27	37				
	30	26	46				
	30	26	56				
	50	17	67				

Continuing the experiment, the coil B was moved a determined distance beyond the plane of A, and the balancing coils again adjusted to silence. The brass ring C was once more caused to disturb the balance, and the new hearing distance was noted. The results of a series of experiments made on the 19th of July, 1881, are tabulated on the preceding page. The battery employed consisted of six bichromate cells connected in series.

These figures show that *the distance from the primary coil* A (fig. 8) *at which the influence of the brass ring* C *became perceptible increased with the diameter of the primary ring, and that the secondary coil* B *required to be projected considerably beyond the plane of the primary in order to obtain the maximum effect.*

The conclusion seemed a natural one that the degree of projection A B of the secondary coil should proportionally increase with the diameter of the primary ring, but the tabulated figures did not fully justify the inference.

The experiments had necessarily occupied a considerable time, and I thought that the difference between the results that should have been observed, according to the above hypothesis, and those that were actually obtained, might have been due to the gradual exhaustion of the bichromate battery employed and to its polarization, although every care had been taken to preserve its power by removing the carbon and zinc plates from the solution, excepting when an observation was made. To test whether the battery exerted any material influence upon the hearing distance, a further series of experiments was made with the same battery.

It will be seen by reference to the tabulated statement shown above that the maximum hearing distance B C had been obtained with a primary ring $11{\cdot}3^{cm}$ in diameter when the distance A B between the primary and secondary coils was one centimeter. This arrangement of the apparatus was therefore adopted throughout the following experiments:

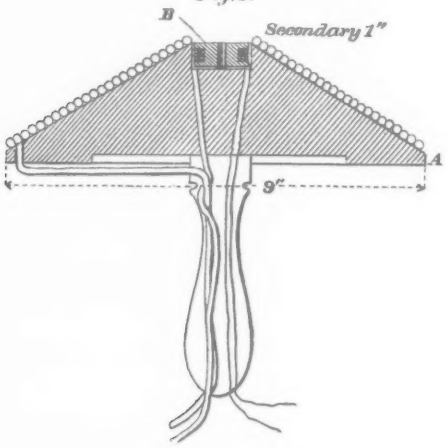
	Hearing distance.
1. Apparatus tried with 1 cell (bichromate battery)---(B C, fig. 8) =	9^{mm}
2. Six cells in series ----------(B C, fig. 8) =	16^{mm}
3. Six cells in multiple arc ----------(B C, fig. 8) =	9^{mm}
4. Six cells in two series of 3 each ----------(B C, fig. 8) =	15^{mm}
5. Same experiment repeated.. ----------(B C, fig. 8) =	$13{\cdot}5^{mm}$
6. Same experiment repeated by Mr. Tainter.....(B C, fig. 8) =	$12{\cdot}5^{mm}$

These experiments proved that battery power *did* exert an influence upon hearing distance, and also that the battery in use was gradually deteriorating.

I concluded, therefore, that if the battery power had remained constant, the hearing distance might not only have been proportional to the diameter of the primary ring, but, in order to attain the maximum effect, the projection of the secondary coil beyond the plane of the primary might also have been found to increase in like proportion.

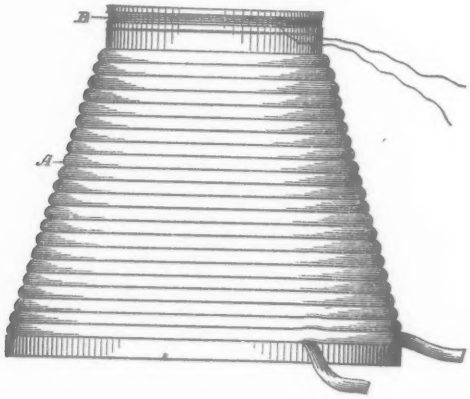
This led me to try the effect of a conical primary coil A with the secondary B at its apex, as shown in fig. 9, but the hearing distance for a bullet was only 3·5^{cm}.

Fig. 9.



Singularly enough Mr. J. H. C. Watts, in Baltimore, had independently arrived at a very similar form of coil, and with the instrument shown in fig. 10 he had obtained at one time a

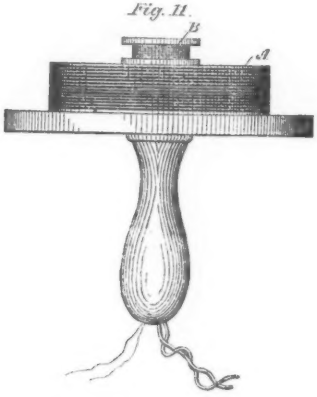
Fig. 10.



hearing distance of 7·5^{cm} (or 3 inches), but from some cause not ascertained he was unable subsequently to reproduce the effect.

The final form of apparatus adopted as the result of the above experiments is shown in fig. 11. With this arrange-

Fig. 11.



ment and a battery of six bichromate elements freshly set up, we were always sure of a hearing distance of at least 5^{cm}, although after the battery had been in use for some time the hearing distance hardly exceeded 4^{cm}.

The following are the dimensions of the coils A B (fig. 11) and their resistance:

Coil A	External diameter	7^{cm}
	Internal diameter	4·5^{cm}
	Depth	2·4^{cm}

Wire used, No. 23 (cotton covered). Resistance, 2 ohms.

Coil B	External diameter	2·3^{cm}
	Internal diameter	8^{mm}
	Depth	8^{mm}

Wire used, No. 36 (silk covered). Resistance, 75 ohms.

The face of the coil B projected beyond the face of coil A 4^{mm}.

The balancing coils were made as nearly as possible the duplicates of A and B. The resistance of the coil of the telephone employed was 75 ohms.

Influence of Battery Power.—The following experiments were made with this apparatus (fig. 11) on July 20th, 1881, to test the influence of battery arrangements upon the hearing distance of a leaden bullet:

I. *Series of experiments with a bichromate battery which had previously been in use for a few minutes.*

	Hearing distance of leaden bullet as observed by—	
	A. G. Bell.	S. Tainter.
	cm.	cm
1 cell	2·4	2·6
2 cells in series	3·3	3·5
3 cells in series	3·7	4·1
4 cells in series	3·7	4·0
5 cells in series	4·0	4·1
6 cells in series	4·3	4·4
6 cells in multiple arc	2·6	2·9
6 cells in two series of 3 each — (00 / 00 / 00) —	3·8	3·7
6 cells in three series of 2 each — (000 / 000) —	4·3	4·0

II. *Series of experiments with a Leclanché battery of twenty cells which had been set up for about one month. It had been kept normally upon open circuit, and had only been occasionally used.*

	Hearing distance.
20 cells in series	3·3cm
20 cells in 10 series of 2 each	3·6cm
20 cells in 5 series of 4 each	4·1cm
20 cells in 2 series of 10 each	3·3cm

Although the battery appeared to be in good condition, a close inspection showed that the connections were dirty, and that one of the zinc wires was half broken through.

The defective cell was now removed from the circuit, and the connections of all the other cells cleaned and tightened.

III. *The following experiments were then made with the Leclanché cells united in series:*

No. of cells.	Hearing distance. cm.	No. of cells.	Hearing distance. cm.
1	2·7	11	3·8*
2	2·8	12	4·2
3	3·0	13	4·2
4	3·3	14	4·2
5	3·5	15	4·3
6	3·5	16	4·2
7	3·6	17	4·2
8	3·8	18	4·2
9	4·0	19	4·2
10	3·8*		

These results are graphically represented in fig. 12.

It will be observed that the hearing distance was carried nearly one-third as far again as at first, simply by increasing the number of cells employed without any other change in the

* Balance not quite perfect.

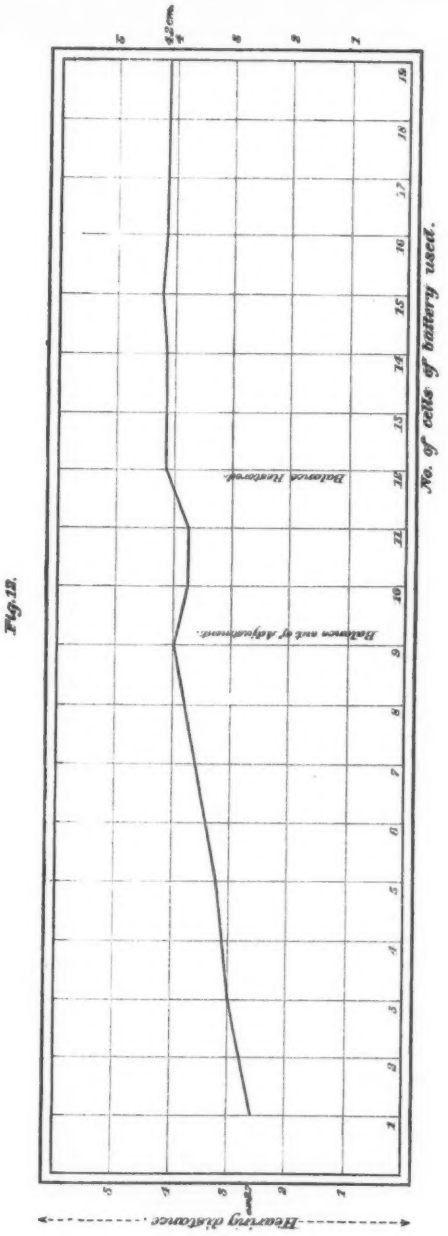

No. of cells of battery used.
Balance restored.
Balance not yet Adjusted.
Hearing distance

Fig. 12.

arrangement. It will also be noticed that the apparatus required to be adjusted to complete silence in order to obtain the maximum effect.

As a general result of all our experiments with voltaic batteries, we find that *it is advisable to use a battery possessing great electro-motive force and slight internal resistance, and to connect the cells in series.*

Experiments upon Living Subjects.—On the 22d of July an experiment was made at the request of Dr. Bliss upon the person of Lieut. Simpson, who had carried a bullet in his body for many years.

When the exploring instrument (fig. 11) was passed over the lieutenant's back a sonorous spot was found, but the indications were too feeble to be implicitly relied upon. Imagination very easily conjures up a feeble sound like that observed, but a number of experiments by different observers seemed to indicate that in this case there was an external cause for the sound—probably the presence of a very deeply-seated bullet. The results of this experiment were communicated to Dr. Bliss in a letter dated July 23d, 1881.

On the 25th of July, Prof. Rowland visited me at Washington, and suggested the use of a condenser in the primary circuit. I had previously discussed this idea with Mr. Tainter, but, not having a condenser at hand, we had been unable to make any experiment. After our conversation with Prof. Rowland, however, we were so impressed by the importance of the point that we obtained a condenser next morning, and found it to produce not only a different quality of sound when the bullet approached the coils, but also to increase the hearing distance of the instrument shown in fig. 11 at least one centimeter.

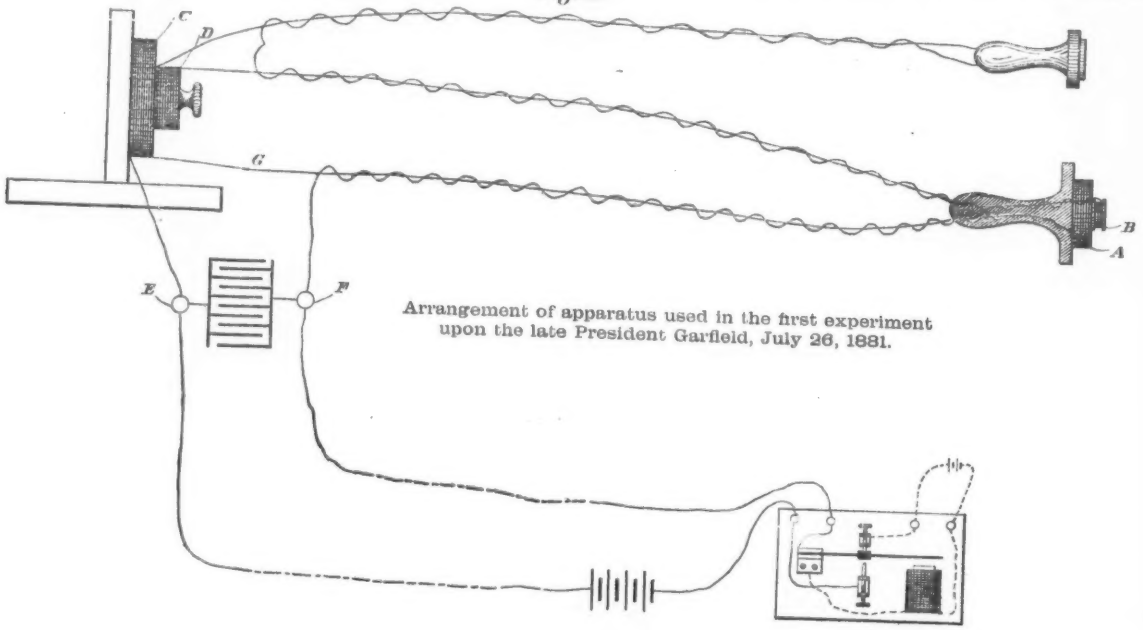
On the evening of the same day (July 26th) our apparatus was carried to the Executive Mansion, and an experiment made upon the person of the President.

From some cause then unknown a balance could not be obtained, and the results were therefore uncertain and indefinite. It was discovered afterwards that a mistake had been made in the mode of connecting the condenser. The latter should have been connected at E F (fig. 13), whereas it was placed at E G, thus influencing only one, instead of both, of the primary coils.

With the condenser properly arranged experiments were tried on July 29 and 30 on three soldiers from the Soldiers' Home who had been wounded during the civil war, namely, John Teahan, Asa Head, and John McGill.

In the case of John Teahan no results were obtained. In the case of Asa Head, who had a buckshot in the cheek, loud

Fig. 13.



Arrangement of apparatus used in the first experiment upon the late President Garfield, July 26, 1881.

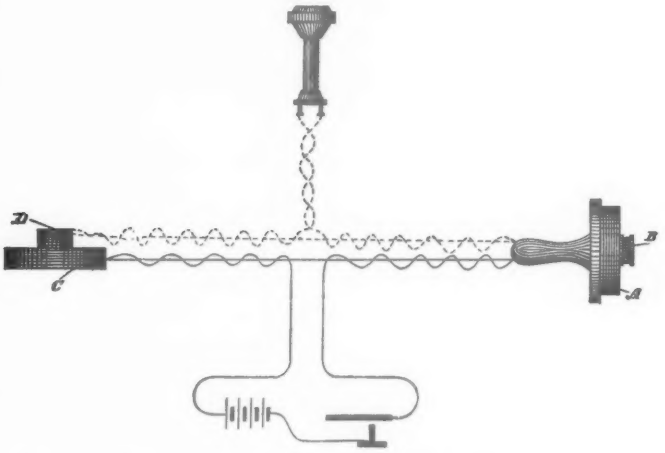
and well-marked sounds were heard in the telephone; and in the case of John McGill, who was supposed to carry a bullet in his back, no results were obtained.

Further efforts were then prosecuted for the improvement of the apparatus.

Further experiments to improve apparatus.—Our attention had hitherto been directed chiefly to modifications of the exploring instrument. We now investigated the effect upon the hearing distance, of the coils used to obtain a balance.

The following experiments, made July 29, 1881, bear upon the point:

Fig. 14.



Exp. 1. (See fig. 14.) Resistance of primary A of exploring instrument, 2 ohms; resistance of primary C of balancing coils, also 2 ohms; resistance of exploring secondary B, 140 ohms; and of balancing secondary D, 120 ohms.

Result: Hearing distance of bullet from explorer A B, 3·5^{cm}. Hearing distance from balancing coils C D, also 3·5^{cm}.

Exp. 2. (See fig. 15.) Same exploring coils as in Exp. 1, but balancing coils consisted of a flat primary, E—resistance, 5·30 ohms; and flat secondary, F—resistance, 83 ohms. The adjustment was made by sliding the secondary coil upon the primary until a position of silence was obtained.

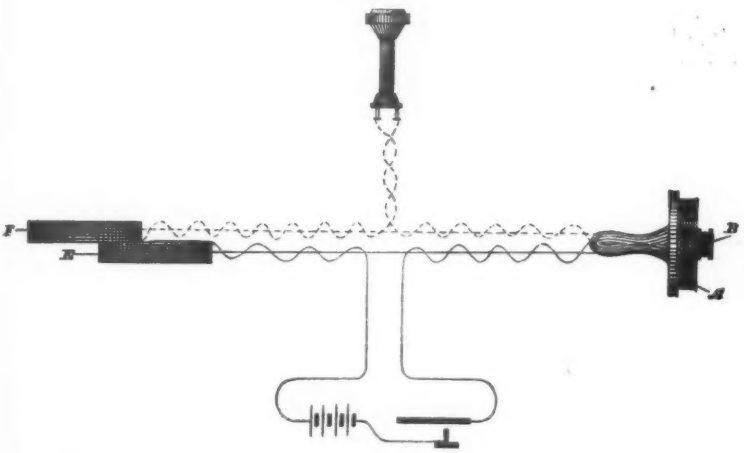
Result: Hearing distance from explorer A B, 1·5^{cm}. Hearing distance from E F, 3^{cm}.

As a general result of our experiments we found that *every increase in the resistance of the balancing coils* (*especially the primary*) *reduced the hearing distance of the exploring instrument,*

and it became therefore desirable to do away with this source of resistance as much as possible.

Return to original form of apparatus.—This led us back to the original form of apparatus that had first occurred to me (see fig. 1), in which a single pair of coils was employed. A few other experiments, made July 29, 1881, will show the importance of the point attained.

Fig. 15.



Exp. 3. The two flat coils E F used in experiment 2 were arranged as in fig. 16, so as to form a balance by themselves.

Result: Hearing distance, 7^{cm}.

In all these experiments the battery used consisted of four cells (Leclanché.)

Fig. 16.

Exp. 4. The same coils used in Exp. 3 were tried again, as shown in fig. 16, but with a battery of eight cells (Leclanché.)

Result: Hearing distance, 8·7^{cm}, or nearly 3½ inches—a result quite unprecedented in our experiments.

The following are the dimensions of the coils E, F.

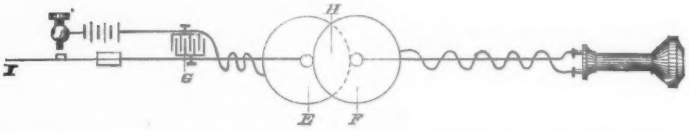
Coil E	External diameter	10 cm
	Internal diameter	2·5^{cm}
	Depth	1 cm
	Wire used, No. 23, (silk-covered.)	
Coil F	External diameter	10 cm
	Internal diameter	2·5^{cm}
	Depth	1 cm
	Wire used, No. 28, (silk-covered.)	

Exp. 5. The same coils E F, used in Exps. 2, 3 and 4, were tried once more with a battery of six large bichromate elements, and with a condenser, G, in the primary circuit as shown in fig. 17.

Result: Hearing distance 13^{cm}, or more than 5 inches.

This great increase in hearing distance seemed to be chiefly due to the condenser, for upon disconnecting it the hearing distance was little more than 9^{cm}, but further experiments proved that other causes also contributed to the result.

Fig. 17.



Exp. 6. When the condenser was in circuit and the leaden bullet close to the coils (arranged as in fig. 17) the sound produced by the telephone was a musical note whose pitch was the same as that normally produced by the vibration of the reed of the interrupter. Mingled with this tone could be distinguished a number of feebler tones of very much higher pitch. Upon withdrawing the bullet gradually from the coils the fundamental sound became fainter, and one of the high upper-partial tones gradually acquired prominence; and at a distance of about 8 or 9^{cm} the fundamental could no longer be distinguished, but the high tone persisted, and was clearly audible up to a distance of 13^{cm}. The effect was very striking, and when the bullet was moved to and fro parallel to the plane of the coils E F at a distance of about 10^{cm}, the telephone emitted a shrill whistling sound each time the sensitive area (H) was passed.

It was noticed that other metals, such as iron, brass and copper, did not seem to reinforce this high tone to any great extent, but brought out the fundamental at every distance where an effect was produced.

Exp. 7. The condenser G (fig. 17) was removed from the circuit and the leaden bullet held about 4 or 5^{cm} from the coils E F. The fundamental tone was heard, and the characteristic upper partial could also be distinguished, but it was only faintly audible. Upon now suddenly replacing the condenser the high upper-partial tone was instantly reinforced as if by a resonator.

Exp. 8. The rheotome employed to interrupt the primary circuit (which had been placed in a distant room) was found to be vibrating badly. The reed I of the instrument (see also

fig. 5) was rattling against its contact pieces, thus producing an impure sound, and I could distinguish among the upper-partials the tone that had been reinforced by the condenser. Upon screwing up the contact pieces so as to improve the vibration I could no longer distinguish the particular upper-partial referred to, and upon returning to the room in which the coils E F (fig. 17) were placed I could no longer detect the effects noted above in Exps. 6 and 7, and the hearing distance did not exceed 9^{cm}.

The peculiar effects obtained with the arrangement shown in fig. 17 *thus seemed to depend* (1) *upon a particular kind of vibration of the reed of the interrupter, producing a certain high upper-partial or overtone* (2), *upon the use of a condenser acting as a sort of electrical resonator for this tone, and* (3) *upon the use of the metal lead.*

Mr. Marean, of Washington, kindly lent me a number of condensers used by the Western Union Telegraph Co., and we found, upon connecting them with the coils E F, as shown in fig. 17, and, holding a leaden bullet near the coils, that each condenser reinforced a high upper-partial of different pitch. We arranged the condensers so that they could be successively introduced into the circuit with great rapidity. The effect was very curious, and sounded somewhat like a Scotch air played upon the bag-pipes. The low hum of the fundamental could be heard continuously, like the drone of the bag-pipe, while the higher tone changed its pitch with each change of condenser.

The pitch of the high tone reinforced seemed to depend upon the electro-static capacity of the condenser employed, but the exact relation between the two has not been ascertained. In experiments 5, 6, 7, 8, and the subsequent experiments described above, the battery employed consisted of six pairs of carbon and zinc plates of large area placed in a solution of bichromate of potash containing sulphuric acid.

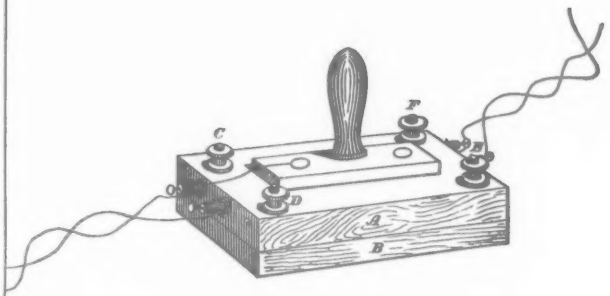
The effects noted above were not produced satisfactorily when the battery was much run down, nor were they obtained with a Leclanché battery which had been set up for some time, but which appeared to be in good condition.

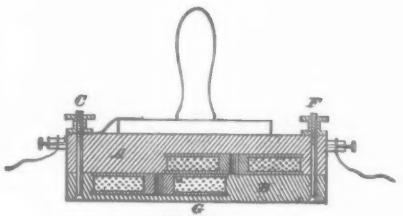
It is evidently necessary in order to produce this characteristic high tone to use a battery possessing considerable electromotive force and slight internal resistance.

Our experiments had reached this stage when, on Saturday, the 30th of July, 1881, I was requested to make another trial upon the person of the President at the evening dressing of the wound.

At this time, however, we had no exploring instruments completed excepting one or two like that shown in fig. 11; for it will be understood that the promising results noted above

Fig. 13.





Section.

Apparatus used in the second experiment upon the late President Garfield, August 1st, 1881.

had been obtained from coils that were simply placed upon a table and adjusted by hand.

We immediately proceeded to the Executive Mansion with the apparatus shown in fig. 13, prepared to make a trial, if it was deemed advisable; but upon learning of the results of our later experiments the surgeons resolved to postpone any further trial until we could arrange the coils (fig. 17) in a portable form.

By forced exertions the coils were arranged that same night in a wooden case, as shown in fig. 18. This case consisted essentially of two oblong blocks A B. A shallow circular recess was turned out in each block for the reception of one of the coils, and the two blocks were held together by four pins of ebonite, C, D, E, F, which passed up through slots in the upper block and were secured by ebonite thumb-screws.

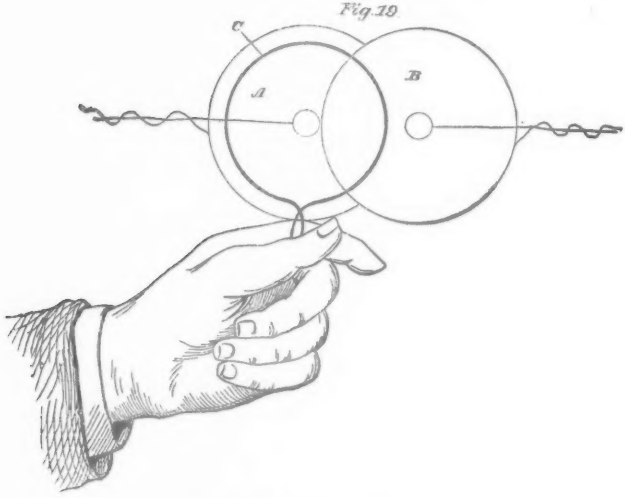
When the instrument was completed I found to my great distress that a balance could not be obtained by any adjustment of the apparatus. There was a position of minimum sound, and the telephone responded to a bullet presented to the central part G of the instrument; but the hearing distance did not exceed 3 or 4^{cm}, whereas we had obtained with the same coils before the construction of the wooden case a perfect balance and a hearing distance of 13^{cm}.

After numerous unsuccessful experiments had been made to ascertain the cause of the difficulty it occurred to me that if two adjoining convolutions in one of the coils, made contact at any point, a circuit of low resistance would be formed (a single ring of wire, in fact), in which the induced currents might circulate without reaching the telephone connected with the apparatus. I had previously measured the resistance of the coils without discovering any defect, but when I considered the large number of convolutions in each coil it seemed possible that a defect of this kind might exist which could not be discovered by a Wheatstone Bridge, excepting by very delicate and accurate observations. To test whether a short-circuited convolution would produce effects analagous to those observed, a piece of copper wire was bent into an annular form and the ends connected together. On bringing this metallic ring near a pair of coils (A, B, fig. 19), properly adjusted to silence, the balance was loudly disturbed. The copper ring (C) was held as shown in fig. 19, and the balance could not then be restored by any adjustment of the coils. A position of minimum sound was all that could be obtained, and the hearing distance was enormously reduced. This was *prima facie* evidence of the nature of the defect.

The coils (fig. 18) were then removed from their case, but a cursory examination revealed no defect. Upon trial, however

(being arranged, as formerly, in fig. 17), a balance could not be obtained, and the hearing distance was only about 4^{cm}. The defect was thus definitely located in the coils themselves.

Fig. 19



Upon close examination it was noticed that the outside convolutions of the primary coil were slightly frayed at one part, but it appeared hardly possible that so great a defect could be due to so apparently slight a cause. However, to test the matter, I removed the outside layer of wires and then tested the coils again.

Result: The defect had vanished—a perfect balance was obtained, and the hearing distance was again 13^{cm}.*

* These experiments have revealed the cause of the extreme difficulty always experienced in obtaining a perfect balance with coils of fine wire. I have recently used an Induction Balance to test the condition of the helices that were employed in these researches, and have discovered that in a large percentage of cases the insulation was defective. It is possible that some of the results described in this paper (especially of the earlier experiments) may have been vitiated by errors due to defects in the coils that were not suspected at the time. A defect of insulation that is quite immaterial for ordinary purposes may be absolutely fatal to the success of an Induction Balance. Indeed, so much care is required in this respect that it is extremely difficult to obtain coils that are perfectly suitable for an apparatus intended to search out a bullet imbedded in the body. I now make it a rule to test every helix used in Induction Balance experiments by bringing it up to a system of balanced coils like that shown in fig. 19.

1. If the helix is perfect the balance is not disturbed until the terminals of the coil are connected.

2. If there is a break in any of the convolutions the balance is not disturbed, even when the terminals are connected.

3. If a convolution is short-circuited the balance is disturbed, even though

The coils were then replaced in their case and the completed instrument tested. The lower wooden block B (fig. 18) was adjusted by hand as nearly as possible to the position of silence, and then the thumb-screws C, D, E, F were tightened.

The balance now obtained was not quite perfect, but by striking the lower block B, a few smart blows with a wooden mallet we were able to reduce the arrangement to complete silence.

The instrument was then in such a sensitive condition that it could scarcely be moved without affecting the balance. Upon gently swaying it backward and forward a pulsation of sound was heard at every swing.

When the motion was carefully made, so that it was always in the same plane, no pulsations were observed. They only occurred when the inclination of the coils was changed.

This defect was found to be due to the bulging of the thin portion G of the wooden case (fig. 18) under the weight of the enclosed coil, and the simple pressure of a finger on this portion of the case disturbed the balance. The movement of the lower coil when the instrument was swayed about must have been inconceivably small but on account of the extreme sensitiveness of the arrangement it produced a perceptible effect upon the balance.

The pulsating sound did not seem to interfere with the detection of a bullet held in the clenched hand, nor did it seem to affect the hearing distance. I therefore despatched a messenger to the Executive Mansion (Sunday morning, July 31st), with a note for Dr. Bliss, to let him know that the instrument was in a condition to be used, should any necessity arise for an immediate experiment. At the same time I informed him that the apparatus in its present form was very crudely constructed, and that I hoped to improve it very greatly in the course of a few days. On Sunday afternoon (July 31st) we sent to the Soldiers' Home for John McGill, upon whom we had experimented the previous day without results (using the apparatus shown in fig. 11).

Upon trying the new instrument (fig. 18) we had no difficulty in finding a sonorous spot in his back, at the place where the bullet was always supposed to be.

This result was at once communicaied to Dr. Bliss, and in

the terminals are not connected, and the sound produced is the fundamental of the rheotome employed to interrupt the primary circuit.

4. If the insulation is defective the balance is disturbed, although the terminals are not connected, and a peculiar spluttering effect is noticed like that produced by a series of sparks.

I propose to apply this method practically as a means of testing the condition of the helices used in the construction of Induction Coils and those employed in the manufacture of telephones.

reply we were requested to make the experiment upon the person of the President next morning.

On Monday morning (August 1st, 1881) we accordingly removed our apparatus to the Executive Mansion.

The late President Garfield.—During the former experiment (July 26) a sudden sonorous effect had been observed upon passing a point near the spot where the surgeons suspected the bullet to be lodged, but I had been unable to verify this by a second observation, although the exploring instrument (A B, fig. 13) was repeatedly passed over the same place. The sound had been so loud and well marked that I believed at the time it must have been caused by a sudden irregularity in the vibration of the reed of the rheotome used to interrupt the primary circuit, for the arrangement, as explained above, was not perfectly balanced, and any irregularity of this kind would, under these circumstances, have affected the telephone. At the same time the coincidence was remarkable that the exploring instrument should have been at that very time so near the suspected seat of the ball, and this led to the thought that perhaps after all the bullet had been the cause of the sound. I felt confident that the new instrument (fig. 18) would at once decide the question, for the extreme hearing distance of the former apparatus (fig. 13) was only 6^{cm}, and the apparatus shown in fig. 18 was so superior in this respect that if the sound had really been due to the bullet we should obtain with the new instrument distinct and well-marked effects. When the new explorer (fig. 18) was passed over the suspected spot nothing was heard excepting a slight pulsating sound as the instrument was moved to and fro. This was evidence to me that the former sound had been of accidental origin, whether the bullet was there or not. With the view of eliminating any error of observation caused by the pulsations due simply to the movement of the instrument, I lifted the latter (without changing the inclination of the coils) to a height of about 50 centimeters above the body of the President, and moved it to and fro in as nearly as possible the same way I had done at the lower elevation.

I presumed that if the pulsations heard were due simply to the movement of the instrument, they should occur with equal strength at the two elevations; but if any portion of the sonorous effect was due to the influence of the bullet, the pulsations at the two elevations would be different in intensity. I was struck by the fact that, although the sonorous pulsations were very feeble, they were sensibly louder when the instrument was close to the surface of the body than when it was raised. Continuing the exploration, I found a considerable area over which similar effects were noticed, but upon carrying the in-

strument toward the back of the President, the difference between the pulsations produced at the two elevations grew less and less, and finally could not be distinguished.

The difference in the loudness of the sound at the two elevations was so slight that it probably would not have been noticed by an ear unaccustomed to listen to feeble effects, and I feared that the general expectation that the bullet would be found in that part of the body might have led me to imagine a difference that did not exist. For the purpose of eliminating as far as possible any personal error, I requested Mr. Sumner Tainter (who was the only other person present whose ear had been sufficiently trained to be reliable in such an emergency) to repeat the experiments and let me know the result. Upon our return to my laboratory we compared notes, and I found that his observations tallied with mine. He declared he could not obtain a distinctly localized effect, but stated that he had observed a reinforcement of the pulsation over an area of at least two inches in the neighborhood of the spot to which his attention had primarily been directed, and that he was convinced that the bullet was within that area.

It appeared reasonably certain that the area of feeble sound was due to some external cause, and was not simply an effect of expectancy. In the absence of any other apparent cause for the phenomenon, I was forced to agree in the conclusion that it was due to the presence of the bullet, and I so stated in my report to the surgeons. I was by no means satisfied, however, with the results obtained, for no such effects had been observed before in our experiments with bullets. I tried to reproduce the effects by moving the instrument (fig. 18) at different distances over a bullet, but in every case where an effect was produced the sound was quite sharply localized. I thought that perhaps the body of the patient might have affected the result, and so experimented upon a bullet buried in a piece of meat, but no difference of effect was noted. This led me to fear that the extensive area of feeble sound might have been due to some extensive area of metal that was unsuspected at the time, and I proceeded to the Executive Mansion next morning (August 2) to ascertain from the surgeons whether they were perfectly sure that all metal had been removed from the neighborhood of the bed. It was then recollected that underneath the horse-hair mattress on which the President lay was another mattress composed of steel wires.

Upon obtaining a duplicate, the mattress was found to consist of a sort of net of woven steel wires, with large meshes. The extent of the sonorous area having been so small, as compared with the area of the bed, it seemed reasonable to conclude that the steel mattress had produced no detrimental

effect.* I was unable to continue experiments with the steel mattress, as just at this time I was obliged to leave Washington on account of illness in my family. Although I was unable for a long time afterwards to carry on personally induction balance experiments, the investigations were ably continued under my direction by Mr. Thomas Gleason, in the establishment of Mr. Charles Williams, Jr., in Boston.

Experiments continued in Boston.—Mr. Tainter forwarded from Washington drawings of an improved apparatus he had designed to remedy the defects of the instrument shown in fig. 18, in which the case, adjusting screws, etc., were all to be composed of ebonite.

Mr. Gleason constructed for me a number of such ebonite instruments differing slightly from one another in detail, and the apparatus shown in fig. 20 combined the different points that had been approved.

The two coils A B were eccentrically arranged in two circular disks of ebonite, C D, and the adjustment was obtained by means of an ebonite key O, like the key used for tuning pianos, which turned a cam M pivoted in the upper disk and working in a slot N in the lower disk.

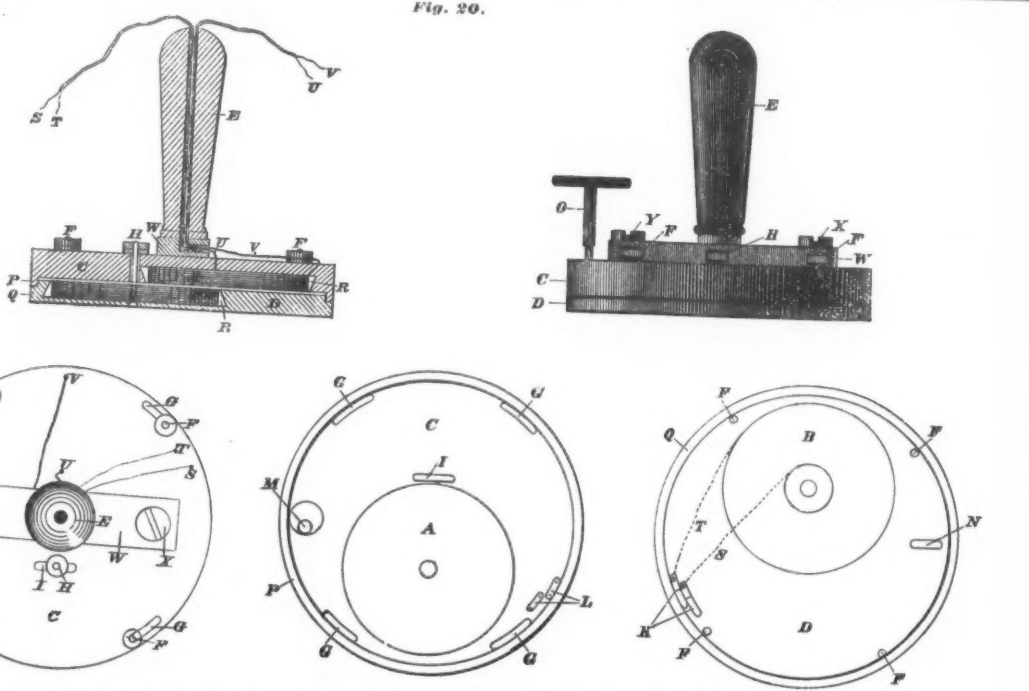
In order to prevent any movement of the coils, excepting that produced by the adjusting-key O, each coil was placed in a recess turned out in its ebonite disk, the edges of which were bevelled as shown at R. Paraffine was then poured in so as to fill up each recess. But this alone did not prevent a slight pulsation of sound when the instrument was swayed from side to side, and a very slight pressure of the finger on the thin portion of the ebonite plate under the coil B was sufficient to destroy the balance.

This was remedied by strengthening this portion by means of a rod of ebonite, which passed up through the center of the coil and through a slot I, in the upper ebonite plate, and was clamped firmly after the adjustment of the instrument by an ebonite thumb-screw H. This, however, increased the difficulties of adjustment. When the coils were adjusted to silence, then the tightening of the thumb-screw H disturbed the balance; and if the thumb-screw H was tightened first, then the adjustment could only be made by a series of jerks, on account of friction. In practice we found it best to adjust the instrument *almost to silence*, and then the tightening of the thumb-screw H completed the balance.

This was the form of apparatus at which we had arrived at the time of the death of President Garfield.

* The death of President Garfield and the subsequent *post-mortem* examination, however, proved that the bullet was at too great a distance from the surface to have affected our apparatus.

Fig. 20.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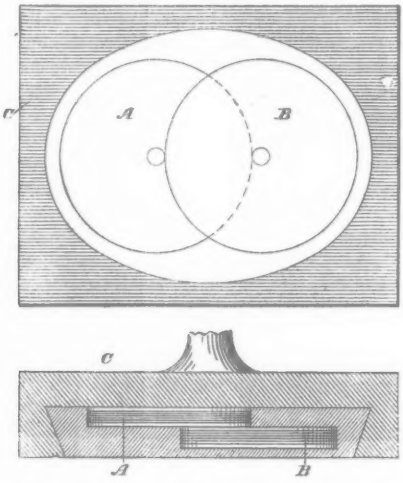
The difficulty of adjusting the coils led me ultimately to the idea of the apparatus shown in figs. 21, 22, 23, 24, which is the most practical form of the instrument yet devised.

The two exploring coils A B (fig. 21) are arranged as shown, in a recess turned out in a single block of wood C.

Fig. 21.

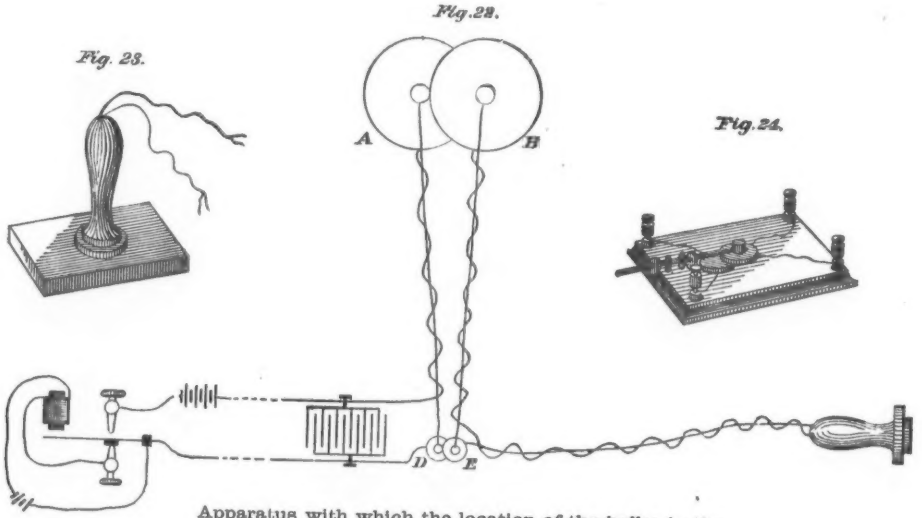


The coils are temporarily connected with a telephone battery and rheotome in the manner shown in fig. 1, so that they may be adjusted by hand to form a balance. When they have been arranged in their position of silence, the hollow in the block of wood C (fig. 21) is filled with melted paraffine. Upon cooling, the two coils are found immovably fixed in one solid cake of paraffine.

As a matter of practice it is found impossible to fix the coils in this way exactly in their position of silence; but by means of two other very small coils, D E (fig. 22), of insignificant resistance, forming a sort of fine adjustment external to the explorer, a perfect balance is easily obtained. In this instrument the swaying of the coils A B produces no effect upon the balance.

The completed arrangement is shown in plan in fig. 22, and the explorer and balancing coils are shown separately in perspective in figs. 23 and 24.

On account of the small size and slight resistance of the balancing coils we were enabled to make the adjustable parts of the balancer of metal without practical interference with the sensitiveness of the exploring instrument, and this gave us the



Apparatus with which the location of the bullet in the body of Col. Clayton was discovered, Oct. 7th, 1881.

power of making very delicate adjustments of the balancing coils.

We found it advisable, however, to avoid placing metal over the sensitive area of the coils as had been done in the instrument shown in fig. 24.

In the balancing apparatus shown in fig. 25 (which is the most perfect one yet constructed), the lever to which the upper coil is attached is made of hard rubber.

In fig. 26 is shown the most convenient form of case yet devised for holding the exploring coils.

Fig. 25.

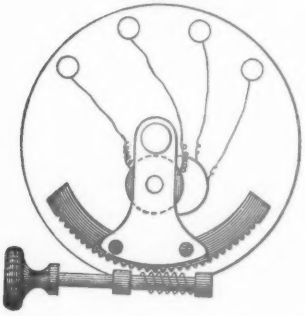
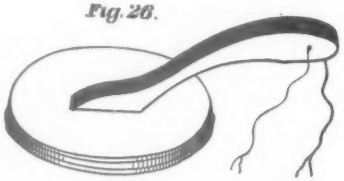


Fig. 26.



By invitation of Dr. Frank Hamilton experiments were made at his office in New York, October 7, 1881, the instruments used being those shown in figs. 22, 23, 24.

As this was the first successful application of the Induction Balance to the discovery of the situation of a ball in the body the position of which was previously unknown, I may be pardoned for entering somewhat into detail.

I shall quote from the Medical Gazette,* of New York, an account of the experiments written by one of the witnesses:

"*The first successful application.*—On Friday, Oct. 7, by invitation, several medical gentlemen,† including the writer, met Prof. Bell at the house of Dr. Frank H. Hamilton, in this city, for the purpose of witnessing the practical application of his improved instrument.

"The first person subjected to experiment was General Calvin E. Pratt, judge of the supreme court of the State of New York,

* See Medical Gazette, Oct. 15, 1881, pp. 347-349.

† "The following are the names of the medical gentlemen who were present, each one of whom verified personally the results and declared his entire satisfaction with every experiment that was made: J. C. Hutchinson, J. G. Johnson and J. G. Allen, of Brooklyn; Elias Marsh, of Patterson, N. J.; Nathan Bozeman, J. H. Hunter, G. Durant, F. Delafield, L. Damainville, W. M. Chamberlain, J. H. Girdner, Frank H. Hamilton and E. J. Bermingham, of New York."

and who is now a resident of Brooklyn. General Pratt, at the battle of Gaines' Mills, June, 1862, this being the second day of the famous seven days' retreat across the peninsula, received a ball in his left cheek, which penetrated through the nares and was lodged in the right antrum. Its presence at this time was recognized by his surgical attendant, Dr. Damainville, and its exact position has been known from that day until this, it having given rise at times to much pain and suffering.

"General Pratt has been seen by Dr. Hamilton and Dr. Damainville occasionally from that time forward, and they have from time to time urged upon him the necessity of its removal. General Pratt, however, was anxious to know whether Prof. Bell's instrument would indicate its presence at the same point as declared by his surgeons.

"The results of the experiment were conclusive and entirely satisfactory to General Pratt, the response being heard distinctly, but rather feebly, by every person present in the room. The feebleness of the response was supposed to be due to the fact that, owing to its situation and the peculiar form of the instrument containing the induction coils, it was impossible to bring the center of its surface very near the site of the ball, the ball being situated very near the depression at the ala of the nose."

"The next patient was Col. B. F. Clayton, who received a wound at the battle of Cedar Mountain, Virginia, Aug. 9, 1862.

"The missile was supposed to be an Enfield rifle ball, and the wound was supposed to be mortal by the medical director of General Banks' staff and his assistants. The ball passed through the sternal end of the left clavicle, and was supposed to have lodged in the muscles under the superior angle of the corresponding scapula. The injury was followed by complete paralysis of the left arm, continuing for a period of six months; and his arm has never yet been completely restored to its normal condition. He suffers a great portion of his time from pains in the arm, shoulder, and portions of the back.

"Several small fragments of bone escaped through a fistulous orifice formed near the seat of the original wound.

"About eighteen months later an abscess opened on the front of the chest below the fifth rib and to the left of the sternum. Through this sinus his surgeon was able to carry a probe upward and backward toward the top of the shoulder several inches, and which sinus was supposed then to communicate with the seat of the ball on the back.

"Pleural adhesions were recognized by the medical attendants as having occurred in the upper part of the left thoracic cavity He has been troubled occasionally ever since the injury with cough, expectoration, and violent palpitations of the heart. A suspicion has even been entertained that the fistulous canal which remained open a period of eighteen months, and then became permanently closed, communicated with the bronchial tubes, but at no time was a suspicion entertained by him or his medical

attendants that the ball was not lodged in the back and there closely encysted.

"We are disposed to mention as an evidence of Col. Clayton's loyalty and faithfulness as a soldier that within six months of the receipt of the injury, and while the wound was still discharging pus and blood, he returned to active duty with his regiment and remained in the field until the close of the war.

"In the presence of the gentlemen assembled Col. Clayton exposed his chest, and Prof. Bell proceeded to move the coils across that portion of his back where the ball was supposed to be situated, the colonel indicating the point underneath the superior angle of the scapula as that which had been fixed upon by himself and all the surgeons who had examined him as its exact seat. Although being buried underneath the scapula, they had not been able to verify their diagnosis by the sense of touch. Repeated examinations were made over this region without any response both by Prof. Bell and several of the gentlemen who were present.

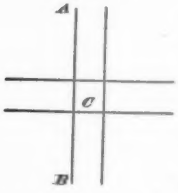
"The instrument was then moved in every direction across the back and shoulders with the same result. There was an evident feeling of disappointment on the part of Prof. Bell and all the gentlemen present, for no one entertained a doubt up to this moment that the situation of the ball was known and correctly stated by Col. Clayton.

"It was not until the lapse of half an hour, and a thorough examination on the part of Prof. Bell to determine if there was not some imperfection in the working of the apparatus, that it was suggested to move the instrument along the front of the chest.

"This was done by Prof. Bell, and immediately he exclaimed: 'I have found it.' And such was evidently the fact, as was verified by the personal examination through the telephone by every gentleman present. The response when the instrument was moved over the seat of the ball was loud and distinct, and left no room for doubt."

After all the visitors present had had the opportunity of verifying my discovery of the sonorous spot on the chest of Colonel Clayton, experiments were made to determine as accurately as possible the exact position of the ball.

Fig. 27.



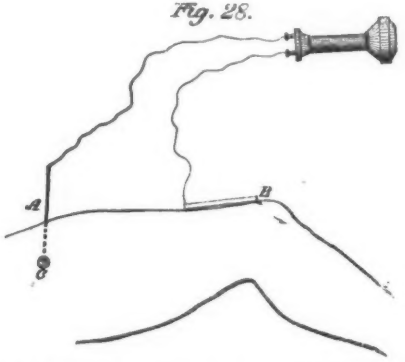
The exploring instrument (fig. 23) was first held over that part of the chest where the maximum sound was obtained. The instrument was then moved slowly toward the left until the sound could no longer be perceived. The position of the center of the instrument was noted, and a vertical line (A B, fig. 27) was drawn with ink upon the skin through that point. This line indicated the boundary of the sonorous area toward the left. The experi-

ment was then repeated by moving the instrument from the point of maximum sound toward the right, and also upward and downward, giving us the four boundary-lines shown in the diagram. (Fig. 27.) The bullet was thus located within a square, C, of about one inch.

"The exact situation of the ball," as described in the Medical Gazette, "was found to be within the thorax, probably in immediate contact with the inner surface of the ribs, the point being a little to the left of the sternum, between the third and fourth ribs, and two or three inches above the cicatrix on the front of the chest, where the sinus, long since closed, had evacuated itself, and in a direct line from this cicatrix toward the left shoulder, which indicated the line of the track of the original sinus."

Experiments with Needles.—During my absence from Washington and from all conveniences for experimenting personally with induction balance apparatus, I devised a method of verifying the indications of the induction balance and of ascertaining the exact depth at which a bullet lies beneath the surface. This method was communicated through Dr. Woodward to the surgeons in attendance on President Garfield, and it was made the subject of a special paper presented to the French Academy of Sciences, Nov. 7, 1881.

Fig. 28.



This method, although involving extremely slight pain, would ordinarily be used only as a preliminary to an operation for the extraction of a bullet. The arrangement is shown in fig. 28. A fine needle A is connected to one terminal of a telephone, and the other terminal makes contact with a plate B, preferably of the same material as that composing the needle. Place this metallic plate B against the surface of the patient's skin and thrust the needle into that portion of the body where the bullet is believed to be lodged. When the point of the needle

makes contact with the surface of the bullet C, a galvanic battery will be formed naturally within the body, the two poles of which are respectively the leaden bullet C and the metallic plate B. Under these circumstances a click will be heard from the telephone each time the bullet is touched by the needle. This has been verified by experiments upon bullets buried in a joint of meat The click, though feeble, is unmistakable.

I have no doubt that this method of exploration alone, without the induction balance, would prove of great service upon a field of battle where the employment of complicated apparatus is impossible. Mr. Thomas Gleason has recently communicated to me the particulars of an experiment he witnessed, in the course of which this method was tried upon a living subject. The surgeon who conducted the experiment was unable to obtain any response from the induction balance employed, although from certain indications apparent to the sense of touch he believed that the bullet was located in the part of the body submitted to experiment.

To verify his supposition a needle connected as above (fig. 28) was thrust into contact with the hard substance perceived, but no response was made by the telephone. The surgeon, however, believing that the bullet had been found, etherized his patient and proceeded with an operation, but discovered, when too late, that the bullet was not there.

Further modifications of Induction Balance.—I sailed for Europe early in October, 1881, and have had no opportunity since of continuing my researches until quite recently. While I was in Europe, however, Mr. Sumner Tainter devised a new kind of induction balance which deserves mention here. The results obtained with this apparatus in its present form (fig. 29) are not to be compared with those produced by the best instruments described above, but there are undoubtedly great possibilities of future development.

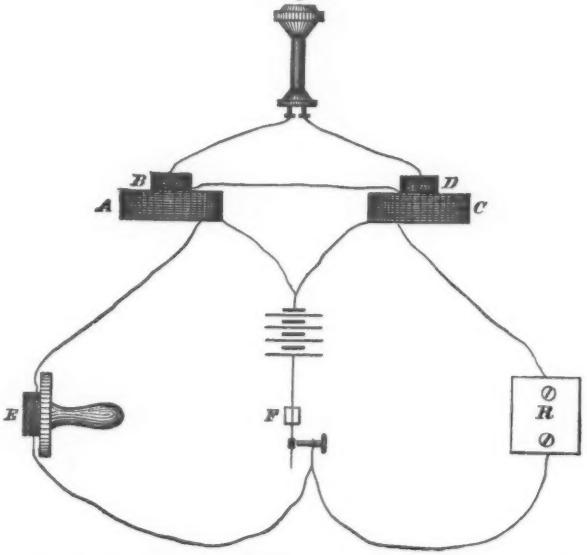
The important feature is that the exploring instrument E consists of *a single coil*, so that there is no possibility of any part of the explorer getting out of adjustment. All the adjustments are made upon the stationary part of the apparatus.

The current of the battery is divided between two equal circuits. One of the primary circuits contains the coil A and the exploring coil E, and the other circuit the coil C and a rheostat R. Coils A and C are exactly similar; and if the resistance introduced at R is equal to the resistance of the exploring coil E, an acoustic balance can be obtained by the adjustment of the secondary coils B D upon the primaries A C; but if the resistance introduced at R is different from that at E, Mr. Tainter states that no balance is possible.

When the apparatus is adjusted to silence the approach of a bullet to the coil E destroys the balance.

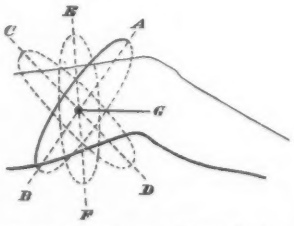
Although the great object of the researches that have been brought before you to-day has been to find that arrangement of balance which will detect a bullet at the greatest distance from the coils of the explorer, it must not be forgotten that in every case the instrument is more sensitive to the presence of a bullet placed *inside* the exploring coils than to one exterior to them. When, therefore, we seek the location of a bullet in one

Fig. 29.



of the limbs, it may be advisable to use an annular coil large enough to slip easily over the leg or arm, as the case may be.

Fig. 30.



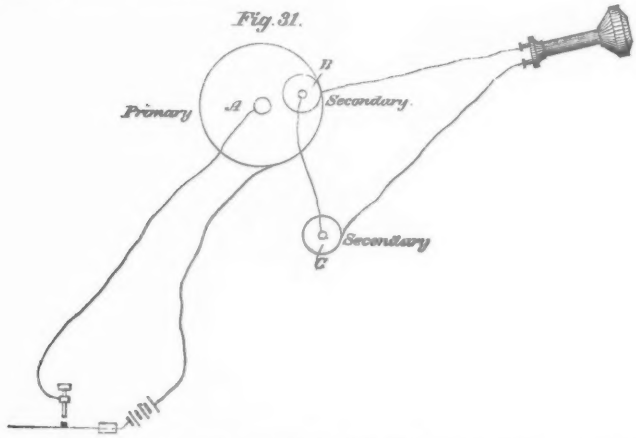
In Mr. Tainter's arrangement the exploring coil E (fig. 29) might simply be a large ring consisting of a number of convolutions of thick wire which could be slipped over the limb, or the ring might consist of two coils, forming one side of a Hughes' induction balance.

In either case the loudest sound will be produced when the bullet is in the plane of the ring, and its exact location should be deduced from three observations. Suppose, for instance, that with the ring inclined in a particular direction the maximum sound is obtained when the ring occu

pies the position A B (fig. 30). We know then that the bullet is in that plane. Now incline the ring in some other direction and explore again. Let the position of maximum sound be now C D. We know then that the bullet is somewhere on the straight line formed by the intersection of the planes A B and C D. It is only necessary then to make a third observation with the apparatus so inclined that the plane of the ring cuts this straight line, for instance, the position E F. The point of intersection of the three planes G is then the exact point occupied by the bullet.

I shall conclude this paper by the description of an experiment made in Newport, R. I., a few days ago. The results are so unprecedented in my experience that I feel they cannot be received as implicitly reliable until the experiments have been repeated and verified.

Fig. 31.



I had arranged upon a table three coils (as shown in fig. 31). The large flat primary coil A was connected with a battery of four Bunsen elements and an interrupter, as shown, and the two small secondaries of fine wire, B C, were connected with a telephone.

The secondary B was moved about on the primary A until a position of silence was obtained. Upon bringing a leaden bullet near C the balance was disturbed and a distinct sound produced from the telephone. There is nothing very strange about this when we know that the distance between A and C was only 15 centimeters, so that C was well within the field of induction of A; but what did seem extraordinary was that the approach of the large steel blade of a penknife to the coil C produced no effect! The iron diaphragm of a hand telephone

brought close up to the coil C produced no sensible disturbance of the balance, whereas a small disk of lead produced quite a marked effect. A disk of copper the size of a telephone diaphragm also produced a good effect, but the sound was not sensibly louder than that due to the small leaden disk. A diaphragm of zinc occasioned a feeble but distinct disturbance of the balance. It is unfortunately the case that in all the forms of induction balance described above, lead gives the poorest effect of all metals. If people would only make their bullets of silver or iron there would be no difficulty in finding them in any part of the body! In the apparatus shown in fig. 31, however, it seems (unless subsequent experiments should reveal some fallacy) that we have an arrangement which is sensitive to lead and not to iron, or, at all events, which is more markedly influenced by lead than iron.

It is hardly necessary to state that when the coil C was removed to a considerable distance from the primary A, no effect was produced by the approach of metal to the coil C.

I have in this paper brought before you an outline of a labor of love pursued through many anxious days and sleepless nights. However imperfect or disappointing may be the results so far achieved, they are sufficiently encouraging to enable us to look forward with confidence to the attainment of still greater perfection.

I hope to continue these researches in the future; and certainly no man can have a higher incentive to renewed exertion than the hope of relieving suffering and saving life.

ART. IV.—*A Method for Determining the Rate of Tuning-forks;* by ALBERT A. MICHELSON.

THE tuning-fork is already employed to a great extent as a measurer of small intervals of time, and this use promises to become more extended as its advantages become more fully appreciated. Any method which will facilitate the operation of finding the rate, or increase its accuracy should therefore merit consideration.

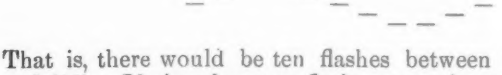
The following plan appears to be open to fewer objections than any now in use, and its accuracy is limited only by the accuracy of the pendulum.

The fork to be rated, for example an Ut_2 making about 128 double vibrations per second, is compared with an Ut_2 kept in vibration by electro-magnets and which shall be designated EUt_2, and this is compared directly with the seconds pendulum, and then the two forks are once more compared, to make certain that EUt_2 has not changed in the interval. Thus Ut_2 is

determined. The whole operation may be performed in less than ten minutes.

To determine the rate of EUt_2 we will suppose that this is within a small fraction of a whole number of vibrations per second, and that this whole number is known; say 128 v. s. A mirror is attached to one prong of EUt_2 and in front of this, and at a distance of two or three feet, is placed a Geissler tube. This last is illuminated once every second. The tube itself is continuously illuminated and its image in the mirror presents the appearance of a broad band with well-defined edges. Against this the narrow flash is projected.

Evidently if EUt_2 makes an exact whole number of vibrations per second, then this flash will always find the fork in the same phase of vibration, and consequently its image will always appear at the same part of the band. If, however, the fork makes, say 128·1 v. s., then it will occupy successively the positions



That is, there would be ten flashes between the positions (0) and (10). If, therefore, ten flashes occur in one "period" then the whole number 128 is to be increased (or diminished) by one-tenth; and in general if a flashes occur in one period then EUt_2 makes $128 \pm \frac{1}{a}$ vibrations per second.

Since EUt_2 vibrates continuously the number of periods which may be counted is unlimited, hence a can be found with any desired degree of accuracy.

It was found that the chief difficulty in executing this plan lay in the imperfections of the break-circuit. If thereby the seconds intervals differed as much as 0·002 seconds, then the operation would be impracticable, on account of the irregularities in the position of the flashes. A great many break-circuits were tried, and the one which was finally adopted as being the most reliable and giving the least trouble was the "mercury globule." Even this, however, in its usual form was unsatisfactory. A great improvement was effected by narrowing the globule in the direction of the swing of the pendulum, by placing it in a small tube whose upper end was flattened. If the current from a "bi-chromate" cell is interrupted by this break-circuit the mercury oxidizes rapidly, and the flashes (given by a small induction coil through the Geissler tube) become irregular.

To obviate this difficulty, the circuit of a "gravity" battery was interrupted, and this worked a relay, which in turn inter-

rupted the circuit of the induction coil. The results thus obtained left nothing to be desired.

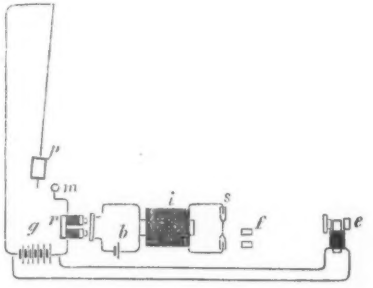
In order that the rate of EUt_2 remain constant, it is necessary that the current passing through its electro-magnets be constant. Hence the necessity for constant batteries, which, however, have a comparatively great resistance. Several might be joined in parallel circuit, but it was found that much better results were obtained by using six "gravity" cells in series, and using fine wire magnets. Such a battery will keep the fork in vibration indefinitely with but little alteration in its rate except that due to variations in temperature.

In comparing the forks a convenient plan is to weight the EUt_2, so that it gives with the fork to be rated about 9 beats in 10 seconds, and then to time the "coincidences" between the beats and the ticks of the pendulum. By this means the comparison can be much more accurately determined than by counting the beats for sixty seconds. This may also be done by the optical method. It was found that the "gravity" battery which kept the EUt_2 in vibration could serve at the same time to work the relay.

The whole arrangement is shown in fig. 1, in which, for clearness, all the parts to the right of *i* have been shown in the plane of the drawing, instead of at right angles.

1.

p, pendulum.
m, mercury globule.
g, gravity battery.
r, relay.
b, bichromate battery.
i, induction coil.
s, Geissler tube.
f, fork to be rated.
e, "electric" fork.



In practice only the even flashes are counted, the odd ones being disregarded. Consequently, if a be the number of these per period, n, the rate of the fork, and 2N, the whole number nearest to $2n$, then $n = N \pm \frac{1}{2a}$. To determine which sign is to be used, EUt_2 is weighted by a very small piece of wax. If a is greater than before, the sign is +; if a is less, the sign is −.

The electric fork may be dispensed with entirely by the following method. The fork to be rated is placed vertical, so that one edge is in the focus of a microscope provided with

cross-hairs. Behind the fork the Geissler tube is placed horizontal. The appearances observed in the microscope at each flash would then be as follow:—

From these we can deduce the rate as before.

This method would probably give results almost if not quite as accurate as the preceding, and has the advantage of being more direct. The nearest whole number may be found by comparison with one of König's standards, or by the following method.

The fork is, in turn, compared with two pendulums, whose times of vibration are t_1 and t_2, t_1-t_2 being small.

Let n_1=number of vibrations of the fork in time t_1.

Let n_2=number of vibrations of the fork in time t_2.

n_1 and n_2 differing from a whole number by less than a small fraction, e_1.

Let a_1=number of beats of pendulum (1) per period=$\frac{1}{c_1}$.

Let a_2=number of beats of pendulum (2) per period=$\frac{1}{c_2}$.

c_1 and c_2 being small fractions less then e_2.

Let N_1=whole number nearest to n_1.

Let N_2=whole number nearest to n_2.

Then

$$n_1+c_1=N_1$$
$$n_2+c_2=N_2$$
$$n_1-n_2+c_1-c_2=N_1-N_2=M, \text{ a whole number.}$$
$$n_1-n_2+c_1-c_2 \text{ is less than } 2(e_1+e_2).$$

If, therefore, $2(e_1+e_2)$ is numerically less than $\frac{1}{2}$ then $M=0$, whence $N_1=N_2=N$.

$$\frac{n_1}{n_2}=\frac{N-c_1}{N-c_2}=\frac{t_1}{t_2} \text{ and } N=\frac{c_1t_2-c_2t_1}{t_2-t_1}.$$

Eight determinations of the rate of an Ut_2 fork, made by the preceding method gave the following results:

Temp. Fahr.	v. s.	v. s. at 60° F.	Diff. from mean.
54·0°	128·134	128·090	+0·003
56·3	128·114	128·087	0·000
58·0	128·102	128·087	0·000
60·0	128·090	128·090	+0·003
62·2	128·077	128·093	+0·006
63·0	128·060	128·082	−0·005
64·5	128·050	128·083	−0·004
73·5	127·984	128·084	−0·003

ART. V.—*On the Relations of the Menevian Argillites and associated Rocks at Braintree and vicinity, in Massachusetts;* by W. W. DODGE.—With a map.

THE well known syenite of Quincy, Massachusetts, occupies an area a mile and three quarters wide with its northern and southern sides running approximately east and west,—a little north of east, and south of west. It forms two principal east-westerly lines of steep sided hills, or ridges cut across by glaciation. From the base of these, the rock extends to some distance on the more level ground. From Quincy, the rock extends into Milton on the west, and a short distance into Braintree on the south.

The northern of the two lines of hills ends near the Old Colony Railroad on the east, but in the southern there is a detached eminence, known as Penn's Hill, east of the railroad. This hill is separated from those to the westward by a valley half a mile broad, in which the local rock, whatever its character, is concealed by stratified gravel and sand there forming a plain about forty feet above high tide, in which the railroad runs, and through which Town River flows from Braintree to its outlet east of Quincy (Center) village.

Some of the several hills may represent independent outflows (the syenite is an eruptive rock), but the valley referred to is in its present shape a channel of erosion and glaciation.

North, east and south of Penn's Hill, between the Cohasset Branch Railroad and Washington Street (the road from Quincy to North Weymouth and Hingham), in Quincy and Braintree, the most abundant surface rock is a fine-grained syenite, which underlies the coarse Quincy syenite, and is entirely distinct from it. The fact that the two are not merely varieties of the same rock seems to have been overlooked. For the purposes of the following account of the two eruptives, the older will be called the Braintree syenite.

The expanse of the older rock is interrupted by bands of argillite, in which at one point occur *Paradoxides* and other fossils.

Stratified Rocks (S on the accompanying map.)—Concerning the stratified deposits at the south shore of Boston Harbor, only such details need be here presented as seem to have significance concerning the relations of the strata and their disposition with reference to older and newer rocks.

Of the stratified rocks in an anticlinal fold bordering on the north the coarser syenite in Quincy, the sandstones and slates on the north side of the narrow conglomerate axis measure,

so far as exposed, 288 feet west of the railroad, 312 at Hough's Neck, the strata being nearly vertical. The conglomerate as seen on the south side of Hough's Neck is penetrated by various eruptives, feldspathic as well as pyroxenic.

THE MENEVIAN OF BRAINTREE, MASSACHUSETTS, AND ASSOCIATED ROCKS. BY W. W. DODGE, 1882.
S = Argillites; L = Lower Syenite; U = Upper Syenite; Q = Quarries.

The coarse-grained, bright-colored syenites in Hingham and the adjoining towns (frequently micaceous), and in Weston, have a strong resemblance to each other, so far as regards the body of the rock. That in Weston is porphyritic with large simply-twinned feldspar crystals; Mr. Crosby has noted the occurrence of the same peculiarity at one place in Hingham.

An area of syenite west of the southern part of Hingham Harbor is nearly surrounded by conglomerate, which like the Roxbury conglomerate contains frequent pebbles of distinctly stratified rock. Pebbles also occur which evidently had their sources in the local representative of what has been named "Shawmut amygdaloid," found in place, for example, north and west of Squirrel Hill, as the Roxbury conglomerate has numerous pebbles of the similar rock which occupies a large area and several small spots in Newton and Needham. The conglomerate and syenite are found together eastward as far as the seashore. South of the Cohasset Branch Railroad, between the Hingham and West Hingham stations, are about 700 feet of conglomerate, sandstone and slate dipping southerly 55°, with much intrusive rock of various character, often amygdaloidal, in one place coarsely porphyritic and containing well-developed crystals of magnetite of good size. Beds of sandstone and slate bend around the western side of the conglomerate and extend northeasterly along the west shore of the town, showing at Beal's Cove a thickness of about 500 feet, there standing nearly vertical, the highest beds (above a dike) inverted to an easterly dip. North and east of Hewitt's Cove are large masses of diabase. In this rock, at one point near the beach at the head of the Cove, calcite has replaced large crystals of triclinic feldspar.

An anticlinal of slates more than a mile long, 1100 feet wide, occupies the valley of Monatoquot River in Braintree, and extends into Weymouth. The strike is about east and west. The strata on the north side dip at 70°, so far as observed, giving a thickness of about 475 feet; on the south the dip is occasionally much lower. The southern half of the fold is overlaid in Weymouth at its eastern end by a light-colored eruptive, chiefly quartzo-feldspathic; and this is cut and capped by diabase, which may also be seen in contact with the slate on both sides of Washington street at the corner of Commercial, in Braintree. At its western end and to some extent on its southern margin, this band of slate passes under hills of drift. Westward, in the northern part of Braintree, the surface configuration shows it probable that the slates continue beneath the surface in that direction.

On the western side of Weymouth Fore River, in the extreme eastern part of Braintree, and along, and also about two hundred feet north of, the railroad west of North Weymouth station, are slates. In the railroad cut (where the strike is about east-west) they may be seen bending over from 85°, the usual dip, to 15° under the masses of eruptive rock at the south side of the railroad. This last named rock, while quite unlike the typical form of the Braintree syenite, resembles a

variety of it which occurs on the north side of the quarry lane leading from Hayward's Creek toward Penn's Hill.

At the trilobite quarry, south of Hayward's Creek, the strike is east-west, the dip 65° south. Passing westward to the other side of the creek, the Braintree syenite is found at the surface, and this in turn disappears, farther in the same direction, under the Quincy syenite, while north of these the slates appear with the same strike, making the full width of the band about 1000 feet, from which the thickness may be estimated at 450 feet.

The next band, more than an eighth of a mile northward, lying between Quincy avenue and South street, is more than 400 feet wide, and over half a mile long. The strata of this fold have high dip; their strike is substantially east and west.

Half a mile east-southeast of Quincy railroad station are 450 feet of slates dipping southward, and with strike N. 75° W. These slates, extending S. 75° E. beneath the surface, would lie along the northeasterly side of the adjoining area of Braintree syenite. In Weymouth, outcrops are found half a mile north of the railroad, near Pearl street on both sides of North street, extending for nearly half a mile, 500 feet wide, with Braintree syenite immediately south of them. At both of these places the slate has frequent large oval cavities partially filled with epidote, which are sometimes irregularly scattered, sometimes distributed along lines of decoloration (perhaps also intrusion) parallel to the stratification plane. Diabase is found with the slate in Quincy (east side of Union street), where its presence, securing immunity from glaciation, accounts for the abundant exposures of the various rocks to the southward. The rocks, not rising to great elevation, are somewhat masked at Quincy Point and North Weymouth by the gravel and sand plain which has been already referred to in its extension west of Penn's Hill. The North Weymouth beds lie in the direction of the strike of the fossiliferous beds at Hayward's Creek, and would naturally be regarded as the eastward continuation of these. Their own strike at North street is N. 80° W., and although nearer Fore River it is west, their westward extension may be parallel to Washington street. It is not improbable, however, that the northern surface limit of the most northerly area of Braintree syenite is determined by glaciation rather than by the actual extension of the rock, and that the slates north of this have, except locally, the more common east and west direction.

There seems to be no reason to doubt that the argillites of all these folds are of the same age. Their maximum thickness appears to be not far from 500 feet. The relation of the argillites and the Hingham conglomerates can be more safely deter-

mined after examination of the relation of the Weymouth and Hingham syenites.

Braintree Syenite (L on the map).—Over a region extending a mile and three-quarters north from the Monatoquot Valley, this rock occupies the spaces between the bands of slate described. Abutting against the steep sides of the folds, it shows straight and prolonged lines of junction. The two rocks may usually be found exposed within a few feet of each other along the contact line, but the actual contact is most readily observed at the southerly margin of the Ruggles' Creek strip of slates. Near the contact, the syenite becomes compact and black or dark brown, porphyritic with occasional crystals imbedded in the ground mass but distinguishable on fresh fractures by the luster of the cleavage planes. This form is found on a face of rock bordering a narrow valley which crosses Main street east of Union, in Quincy (not shown on the map); the presence of drift-covered slates in this channel through the syenite may be safely inferred, although no outcrop can be detected. The syenite is generally light or dull brown, but varies to yellow and to speckled gray. Near dikes of diabase, the rock is blackened, assuming a very different appearance from its usual condition. The feldspar crystals in the typical form of the rock are often three-eighths of an inch long, but are enclosed in a finer ground mass. Quartz is abundant, but in very minute grains, often undistinguishable with the unaided eye. The hornblende is in places well crystallized and plentiful, usually not conspicuous, sometimes is much decomposed.

This rock occupies but a small area in Weymouth, unless rocks south of the railroad are to be included with it; its widest expanse is in Braintree, where it spreads from Weymouth Fore River to the valley west of Penn's Hill. It probably extends southward beyond the limits of the map. It never rises to as great elevation as does the Quincy syenite. West of the Old Colony Railroad, it forms the southern side of a small hill near the Quincy-Braintree line, west of the Granite Branch Railroad. Southwest of Pine Hill, it occurs on Willard street near the town boundary, but northward along the West Quincy valley it does not appear.

Quincy Syenite (U on the map).—The quarries at Pine Hill show this rock to hold inclusions of two kinds,—one a light colored, fine-grained quartzose syenite with white feldspar, the other a porphyritic diabase. The small hill east of Pine Hill, above referred to as made up in part of the lower syenite, is capped with this rock. Its northeast side is composed of it, and there a glaciated ledge near the West Quincy Branch Railroad shows the coarse syenite to be crowded with inclusions of diabase (?), fine grained, black, porphyritic and highly mag-

netic, sometimes pyritiferous. The fragments vary in size from a few inches in longest diameter, to many feet in length. Coarse syenite south of the Monatoquot slates holds inclusions of fine grained syenite.

Penn's Hill is composed chiefly of the Quincy syenite, although based on the older eruptive. The principal area covered by this newer rock at that place is a mile in longest diameter; at various points about its edge, the rock occurs in patches alternating at the surface with exposures of the underlying syenite. It is found at the top of a hillock two hundred yards north of East Braintree station, apparently protected against removal by glaciation by the presence of diabase.

No modification in the Quincy syenite where it is in contact with the underlying syenite has been observed. The older rock may have been yet hot when the more recent covered it. No inclusions of the older in the newer have been identified.

The great abundance of quartz in conspicuous lumps in the upper rock makes it easily distinguishable from the older eruptive. On weathered surfaces the former is rough with these lumps, even when heavily lichened, the latter smooth and of a general yellow or brown color. The variety of the newer rock most quarried is blue, but the brown is also used.

Mr. Wadsworth has published* the result of a microscopic examination of this syenite, both the typical form and the "bands" in it. One of these dikes (?), exposed at a quarry in Milton near the Quincy line, is five feet wide, with a direction E. 2° N., and inclination or dip to the northward, 25°. It meets the rock on each side with a distinct junction. It is finer grained than the adjoining rock, of similar color in the central portion, while in the outer inch or two it is very much lighter colored and in the next two or three inches inward, of intermediate tint.

The rough woodland of western Quincy is much less favorable for accurate examination of the distribution of the rocks, than the cleared, settled and carefully mapped parts of the town. The coarse syenite lies in great hill ranges, and the massive dark gray argillites lying upon the steep hill sides are much covered by fallen debris from the crests of the hills. The slates on the east side of Randolph Turnpike have a strike N. 70°–75° E., and are there exposed for a width of about ninety feet.

Examination of the accompanying map shows that two slate bands pass under the Penn's Hill syenite on its eastern border. The most that can be said as to the identity of the strata that appear from under these wide-spreading masses of eruptive rock at different points is that their similarity of char-

* Proceedings of the Boston Society of Natural History, vol. xix, p. 309.

acter makes it extremely probable that there is no break in their continuity in the prevalent line of strike.

The relation between the Quincy syenite and the adjoining Blue Hill region of southwestern Quincy and southern Milton, in which the rocks are in part at least of sedimentary origin, remains to be determined. The strata at this last named locality may well be examined in connection with the highly altered stratified rocks with associated eruptives at Mattapan in Boston and at northern Hingham.

Diabase.—Dikes are doubtless of frequent occurrence throughout the area discussed in this paper, but no search has been made for them. South of Quincy avenue, one ten or fifteen feet thick runs east and west near the junction of the coarse and fine syenites; and nearly in the line of this dike, northeast of the avenue, the Braintree syenite is cut by a dike one or two inches thick. The dike at the Sheldon & Co. quarry west of West Quincy runs N. 60° W., this like the preceding having a northerly dip. The syenite is injured as a quarry stone by the intrusion of these dikes, but no particular visible change of its character seems to be produced.

From what has been above stated, it will be seen that there are eruptives older than the conglomerates of this region and others younger; also eruptives both older and younger than the Quincy syenite; the dikes which cut the latter have the east-westerly direction (prevalent in Hingham and Weymouth south of the region under consideration) which belongs to those dikes cut across by a system of north-southerly dikes in some places in the vicinity of Boston.

Penn's Hill is strewn with bowlders of stratified rock. A small circle on the map, in the southwestern part of the largest area of Quincy syenite, marks the position of a tower at the top of the hill. The quarry, quarter of a mile or more east of this, is at the base of the hill.

ART. VI.—*Observations of the Transit of Venus made at the Washburn Observatory, Madison, Wisconsin, 1882, December 5–6*; by EDWARD S. HOLDEN.

THE Transit was observed at the Washburn Observatory by two persons independently, viz: by myself, using the 15½-inch Clark equatorial, with the aperture cut down to 6 inches; and by Mr. G. C. Comstock, assistant in the Observatory, using the 6-inch Clark equatorial which formerly belonged to Mr. S. W. Burnham. We were assisted by two of my students, Messrs. Conradson and Pennock. It is hardly necessary to say that both instruments are of the highest excellence.

Preparations for the Transit.—The large telescope had its aperture reduced as described. A positive eye-piece magnifying 195 times, with a field of 11′ 42″, was fitted to one of Clark's reflecting solar eye-pieces. This was carefully focused on the sun and on stars on several occasions, and the tube was set at a mean reading of the focussing-scale.

Marks were put on the tubes by which the positions were recoverable at any time. A pair of cross-wires (platinum) was inserted in the eye-piece and the sun's light was reduced by a Steinheil "moderating-glass." An easy geometrical construction assured me of the exact point of first contact.

The 6-inch telescope was also provided with a Clark's solar eye-piece, to which a positive eye-piece magnifying 176 times was fitted. A pair of crossed platinum wires was also fixed in front of this eye-piece. The focal point and the point of first contact were determined independently by Mr. Comstock and myself.

All the preliminary adjustments remained constant till after the Transit. The time was determined by observations of twenty stars on the nights of December 4th, 5th and 7th. All time-pieces were referred to the Hohwû sidereal clock. The Washington time-signals were received on December 5th and 6th, and it may be mentioned that the resulting longitude of the Washburn Observatory differs from the adopted longitude by considerably less than one-tenth of a second of time. All sidereal times here given are local: all mean times are Chicago mean times, and are $7^m\ 11^s{\cdot}11$ later than local mean times.

Geographical positions.—The position of the large telescope is as follows:

Longitude W. from Washington, $0^h\ 49^m\ 25^s{\cdot}78$. Latitude $+43°\ 4'\ 36''{\cdot}8$.

The position of the small telescope is as follows:

Longitude W. from Washington, $0^h\ 49^m\ 25^s{\cdot}60$. Latitude $+43°\ 4'\ 37''{\cdot}5$.

Observations.—The following is a transcript from my observing-book: "Dome opened $19^h\ 30^m$. $19^h\ 45^m$. Image of sun extremely unsteady. [The times are noted on sidereal chronometer S.]

"I. $13^h\ 8^m\ 0^s \pm$. Through clouds and haze: sun unsteady, and the lightest part of the Steinheil wedge used. I could not have observed with the usual shade-glass. Time uncertain by 5^s or perhaps 10^s, though I think not more than 5^s. Venus entered exactly at the point where wires were set. At $20^h\ 27^m$ (Chicago m. t.) the whole disc of Venus is seen, and a little ring of light outside it. This was not specially looked for, but is first seen now.

"II. (*a*) $13^h\ 26^m\ 59^s$. By prolonging the contour of Venus, mentally, this is the time of geometric contact, though the limbs are connected. (*b*) $13^h\ 27^m\ 29^s$. The contour is inside, but the connection still persists. (*c*) $13^h\ 27^m\ 47^s$. Same as before. (*d*) $13^h\ 28^m\ 0^s$. The first instant that the cusps of the sun meet round Venus. Air extremely unsteady." Everything preceding this was written out before leaving the dome. The minute and second of I. were noted by myself and they are correctly recorded. The minute of II. was noted by Mr. Conradson and it may need a correction of $+1^m$. This affects Mr. Comstock's observations of II. also.

Chronometer Comparisons.

S = (Chronometer)	= M = mean time clock keeping Chicago time.
$12^h\ 45^m\ 25^s$	$= 19^h\ 51^m\ 57^s$
13 38 50	= 20 45 13
H = (Sidereal clock)	= M (Mean Time clock)
$12^h\ 44^m\ 29^s$	$= 19^h\ 48^m\ 0^s$
13 44 50	= 20 48 11

On these observations I have to make the following remarks. (*a*) I should take to be the time of first contact. (*b*, *c*) the ligature persists, but in both of these phases the contour of Venus prolonged by the eye lies inside the limb of the sun, especially so in (*c*). (*d*) This is clearly far past II, but it is the first time that the cusps of the sun meet, and even then they do not persist until about 11^s later. Contacts III and IV were lost. A snow storm set in about 22^h. The sun was not visible at its transit over the meridian. I was particularly surprised at the persistance of the black-drop, which I attribute to the bad state of the atmosphere. Certainly the objective, eye-piece and all the apparatus were in perfect adjustment. It could not have been better. The reductions of these observations are given below.

With regard to the work of Mr. Comstock, I copy from a MS. report which he has handed to me, what relates to the contacts. [The times were noted on sidereal chronometer B.]

"I. $1^h\ 9^m\ 1^s.0$. The planet came about where it was expected. The observation is perhaps 4 or 5 seconds late. The sun's limb was quite obscure and the observation difficult. I think that I saw the body of the planet outside the sun as soon as I saw the nick.

"II. 33^s; 44^s; 55^s; 0^s. At 33^s, a bright line of light shot across from cusp to cusp. At 44^s, another line, equally thin, was seen. At 55^s, cusps seemed to meet for the first time. At 0^s, second contact is certainly past."

Chronometer Comparisons.

H. $12^h\ 54^m\ 30^s{\cdot}0 = $ B. $12^h\ 52^m\ 10^s{\cdot}95$
H. $13\ 35\ 15{\cdot}0 = $ B. $13\ 32\ 56{\cdot}1$
H. $13\ 44\ 54{\cdot}0 = $ M. $20\ 48\ 15{\cdot}0$

The corrections to the time-pieces are tabulated below.

	At I.	At II.
ΔH	$= -\ 2^m\ 43^s{\cdot}56$	$= -\ 2^m\ 43^s{\cdot}55$
ΔS	$= +\ 0^m\ 18^s{\cdot}09$	$= +\ 0^m\ 17^s{\cdot}96$
ΔB	$= -\ 0^m\ 24^s{\cdot}51$	$= -\ 0^m\ 24^s{\cdot}65$

Whence the observed times are (*Chicago* mean times):

	Holden.				Comstock.			
I.	20^h	14^m	$28^s{\cdot}2$		I.	20^h	14^m	$46^s{\cdot}6$
II.	(*a*) 20	33	24·0		II.	(*a'*) 20	33	15·4
	(*b*) 20	33	53·9			(*b'*) 20	33	26·4
	(*c*) 20	34	11·8			(*c'*) 20	33	37·3
	(*d*) 20	34	24·8			(*d'*) 20	33	42·3

The predicted times of I were—

Nautical Almanac	20^h	13^m	10^s	Chicago mean time.
Berliner Jahrbuch		12	20	"
Almanaque Nautico		12	32	"

The predicted times of II were—

Nautical Almanac	20^h	33^m	51^s	Chicago mean time.
Berliner Jahrbuch		32	58	"
Almanaque Nautico		33	9	"

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On an improved Apparatus for Gas Analysis.*—Geppert has described some improvements which he has made in the Bunsen eudiometer and its surroundings in order to lessen the work of reduction. The eudiometer itself, which is 80^{cm} in length, is prolonged 40^{cm} above its closed end by a tube of the same diameter open at top, the whole being supported by a Cardan's suspension attached to a wire. The mouth of the eudiometer opens beneath mercury contained in a cylindrical glass vessel. In the same vessel the open end of a barometer tube dips, the upper and closed end being enlarged to a diameter of 2^{cm}. Over the eudiometer and barometer is placed a glass cylinder 110^{cm} high, 9^{cm} in diameter and $\frac{1}{2}^{cm}$ thick, open at both ends. Its lower end is immersed in mercury contained in a glass battery jar 14^{cm} high and 12^{cm} in diameter. The bottom of this jar is covered to a depth of $1{\cdot}5^{cm}$ with a resinous cement, in which the inside vessel of mercury is fastened. The eudiometer and barometer tubes

being filled with mercury and inverted in the proper vessel, the cylinder is placed over the whole and filled with water. This water enters the prolongation of the eudiometer tube through a lateral opening. By means of a tube passing up through the bottom of the battery jar, the eudiometer tube may be filled with gas, which takes at once the temperature of the water. The levels of the mercury in the eudiometer and in the barometer are read off with a cathetometer. The difference gives the tension of the gas, and the former reading the volume of the gas. By moistening the interior of the barometer bulb, the correction for moisture becomes unnecessary. The water column maintains the temperature uniform and obviates the long standing required when the eudiometer is in the air. The barometer being affected equally with the eudiometer by the water column, no separate correction is needed for this. By means of the tube opening beneath the mouth of the eudiometer, not only may gases be introduced but also liquids for absorption. An oxygen determination by explosion with hydrogen—the eudiometer being held firmly against a rubber pad at the bottom of the mercury vessel—requires only 15 minutes with this apparatus and an analysis of blood-gases only ¾ of an hour.—*Ber. Berl. Chem. Ges.*, xv, 2403, Nov., 1882. G. F. B.

2. *On the Determination of Sulphur in Coal Gas.*—An improved form of apparatus for the determination of sulphur in coal gas has been devised by KNUBLAUCH. The gas is collected in a metallic holder of 20 liters capacity so arranged that it may be filled either with gas or water at pleasure, and serving to measure the quantity. The gas passes from the holder into a combustion tube 9 or 10^{mm} in diameter and 30^{cm} long, in which is a loose plug of platinized asbestus. The end of this tube is drawn out, slightly bent at right angles, and ground in to the upper end of the tube of an absorption bottle. From the lateral tubulure of this a tube passes connecting with a second absorption bottle. Then comes a series of bulbs and finally a wash bottle connected with a meter and a Bunsen pump. By the side of the tube which conveys the gas into the combustion tube is a second tube serving for the simultaneous admission of purified air, drawn in by aspiration. In making an experiment, the holder is filled with gas, the water turned on, and the gas, together with 5 or 6 times its volume of air, is drawn into the combustion tube and over the heated asbestus. The H_2SO_4 and SO_3 from the combustion of the sulphur are absorbed in a solution of potassium carbonate, ten grains to the liter, contained in the absorption flasks. The amount of admixed air is determined from the combustion products passing through the meter. The contents of the absorption bottles are treated with permanganate to oxidize any SO_2, decolorized with oxalic acid, and precipitated with barium chloride; 10 c.c. of a solution containing 7 grams to the liter. The operation requires about an hour and the results vary only 0·2 to 0·3 gram of sulphur in 10,000 liters of gas.—*Ber. Berl. Chem. Ges.*, xv, 2397, Nov., 1882. G. F. B.

3. *On the direct Formation of Zinc Sulphide.*—For showing the action of sulphur on metals, copper foil or iron filings are generally employed. SCHWARZ has called attention to the much more brilliant phenomena attending the use of zinc. When two parts of ordinary zinc dust are intimately mixed by sifting, with one part of washed flowers of sulphur, the resulting mass is readily inflamed with a match, burning like gunpowder with a vivid brilliant flame somewhat greenish in color, and leaving only a slight yellowish-white residue of zinc sulphide. The author was led to the experiment by having an explosion as the result of heating zinc and sulphur in a porcelain crucible in the endeavor to prepare zinc sulphide in the dry way. Indeed, he finds that the above mixture may be inflamed by the blow of a hammer. Tried in the ordinary way in a test-mortar, two grams of the mixed zinc and sulphur produced as much explosive effect as half a gram of gunpowder. This ready union of zinc with sulphur suggested further experiments. If carbon disulphide vapor be passed over zinc dust gently heated, the zinc glows as soon as the CS_2 vapor reaches it, yielding zinc sulphide and depositing carbon in the form of lamp black; forming an interesting lecture experiment. The combination of carbon and hydrogen in the nascent state is effected by passing hydrogen sulphide through CS_2 and then over moderately heated zinc dust. The products are passed, first through a wash-bottle containing KOH to remove the excess of H_2S and then into a gasometer. The gas collected burns with a feebly luminous flame yielding CO_2. On analysis it gave 70 per cent of methane CH_4 and 30 per cent. hydrogen. If in this experiment, H_2S is replaced by NH_3, the reaction takes place according to the equation: $CS_2+(NH_3)_2+Zn_2=(ZnS)_2+CNNH_4+H_2$, forming ammonium cyanide. This desulphuring action of zinc is an important one in organic transformations. Thiocarbanilide treated in this way gives aniline and benzonitrile; thiocarbtoluidide, the paratoluidine from which it was made and tolunitrile; allyl sulphocyanide gave allyl cyanide, and this with alcoholic potash gave ammonia and crotonic acid.—*Ber. Berl. Chem. Ges.*, XV, 2505, Nov., 1882. G. F. B.

4. *Electromotive Force.*—It has been maintained by Exner that there is no known case of chemical action without the development of electricity and also of the development of electricity without chemical action. BRAUN controverts this conclusion and repeats Exner's results. The latter employed a cell with zinc and platinum as elements, with iodine or bromine as the liquid. Notwithstanding the fact that iodine and bromine are elements and cannot therefore be electrolytes, this cell gives with an electrometer a difference of potential and in a closed circuit an electrical current. Exner believes that the cause of this current is to be sought in chemical action. According to his statement, wherever a chemical change results in a difference of potential, an electrical current results whether the different metals are immersed in an electrolyte or not, as long as the liquid can conduct electricity.

Braun endeavors to show that Exner reasons in a circle, since as soon as chemical action enters, the combination ceases to consist of elements, and it is necessary to show that the existing combinations are not conducting electrolytes. Braun shows that Exner did not take sufficient precautions to ensure the purity of the iodine and bromine which were employed, and also to prevent the presence and disturbing influence of the aqueous vapor of the air. He concludes from the repetition of Exner's results that the conclusions of the latter are untenable. There are numerous cases in which we have a development of electricity without chemical action, and also strong chemical action without the development of electricity. A zinc and a copper plate in contact give a difference of potential; by their mutual attraction they can give out a certain amount of work. Their action can be represented by a piece of iron and an attracting permanent magnet; the removal of the iron requires work to be done and the attraction of the iron by the magnet affords work. This action of a permanent magnet on iron, in the case of dynamo machines, can play as great a function as the contact of Zn | Cu in a battery. Exner asserts that the electricity apparently due to contact is at the cost of the heat of oxidization. Braun says that this is equivalent to maintaining *à priori* that the permanent magnet affords heat at the expense of some process of oxidization.

Having criticized Exner's results, Braun shows how important the study of electromotive force is to the subject of thermal chemistry. A part of the matter in the series of difference of potential persists in that order in which the materials dispossess each other. While taking into account the heat of combination and Berthelot's principle of maximum work this ought not to happen; for instance, mercury is displaced by copper in Hg_2Cl_2 notwithstanding the greater heat of combination of mercury. The affinity of platinum and gold on the one side and copper and silver on the other toward chlorine stands in no relation to the thermal development (*Wärmetonungen*). From purely *à priori* considerations Braun thinks that it is possible that chemical changes are dependent upon the thermal condition; he, however, is convinced that the fitness for mechanical work of a chemical process determines the chemical change. If, for instance, the entire thermal development due to a process is zero, still exchanges can take place in which that combination results which is more stable in reference to heat. The direct chemical process which goes on without the development of electricity results in lowering the fitness for work of the entire matter. For Berthelot's principle, which can be entitled the principle of maximum development of heat, Braun substitutes the principle of maximum fitness for work. Berthelot's principle would then be a special case of the last, and would apply at the absolute zero of temperature, and the departures from his principle would be greater the nearer the temperature at which the investigation is conducted approaches to the dissociation temperature of the materials employed.—*Ann. der Physik und Chemie*, No. 12, 1882, pp. 593–642. J. T.

5. *Objections to Siemens' New Theory of the Sun.*—M. FAYE has made a calculation of the amount of matter which would be added to the solar system by Dr. Siemens' hypothesis. This matter would be attracted to the sun and stars and would increase their mass. A liter of air containing the requisite amount of aqueous vapor weighs at least 1 gram at ordinary pressure. At a pressure of $\frac{1}{2000}$ which is required by Dr. Siemens, this will amount to 0·0005 grams, and a cubic meter will weigh 0·0005 kilograms. If we consider the solar system as a sphere which will include the planets as far as Neptune, the weight of the extremely rarefied matter added to the solar system would be in kilograms, $\frac{4}{3}\pi(6400000\times24000\times30)^3\times0{\cdot}00065$ kilog.; the weight of the sun is $\frac{4}{3}\pi(6400000)^3\times5{\cdot}6\times324000$ kilog. The first is 100,000 times as great as the second. And this amount of matter would be added to the solar system.—*Comptes Rendus*, Oct. 9, 1882, p. 612.

M. G. A. HIRN presents two objections to Siemens' new theory of the sun. The first is based upon dissociation effects produced by the great heat of the sun. It is perhaps true as Siemens asserts that the compounds which are dissociated under his hypothesis by the effect of the sun in space, in returning toward a center of force like the sun can recombine and restore the lost energy to the sun, but these elements reformed at a certain distance, in falling to the center of the sun, would be dissociated again and would use up the heat they gave off in becoming compounds again, and therefore no gain would be made by the cycle of operations. The second objection urged is the following: If the solar radiation or the radiation of a star is employed in this work of chemical dissociation of the hypothetical matter disseminated through space, the intensity of the light of the star should suffer, and their light should diminish much more rapidly than the law of inverse squares of the distances. Hirn also gives a numerical calculation to support M. Faye's objections to Siemens' hypothesis.—*Comptes Rendus*, Nov. 6, 1882, pp. 812–814. J. T.

6. *Comparative observations upon telluric and atmospheric lines of the spectrum, for the study of absorption of the atmosphere.*—The atmospheric lines in the solar spectrum afford a means, according to CORNU, of obtaining the absorption of the atmosphere. If ε is the total quantity of the absorbing substance, and if, at two different periods, one observes in the solar spectrum the equality of intensity of the telluric line produced by this absorption with the same metallic line at two different altitudes h of the sun, the relation $\frac{\varepsilon}{\sin h}=\frac{\varepsilon'}{\sin h'}$ results. Certain groups of telluric lines can be selected; these are specified in Cornu's paper. —*Comptes Rendus*, Nov. 6, 1882, pp. 801–806.

JANSSEN had previously called attention to a method analogous to that proposed by Cornu, in which the study of the spectrum of aqueous vapor was conducted by means of a tube which was filled with this vapor, and a comparison was made with

the telluric lines in the spectrum. He commends the ingenuity of Cornu's method and reviews the history of the discovery of telluric lines.— *Comptes Rendus*, Nov. 13, 1882, pp. 885–890. J. T.

7. *The Electrical Congress.*—The International Electrical Congress which has lately been in session in Paris is "the outgrowth of the Congress of Electricians which was held a year ago in Paris. That body requested the French government to invite other nations to unite in constituting three international commissions for the study of the following problems:

I. A redetermination of the ohm.

II. (*a.*) Atmospheric electricity. (*b.*) Protection against damage from telegraphic and telephonic wires. (*c.*) Terrestrial currents on telegraphic lines. (*d.*) Establishment of an international telemeteorographic line.

III. Determination of a standard of light."

The Congress assembled, according to this request, in Paris, October 16, 1882, and adjourned on October 26, 1882, to the first Monday of October, 1883. It was concluded by the Congress that there is too great discrepancy between the various values of the ohm which have been obtained by different observers to enable a decision to be reached in regard to its value. All the governments participating in the Congress are appealed to by France to encourage independent redeterminations of the value of the ohm, and of the Siemens' mercury unit. The Section on Earth Currents and Lightning Conductors recommended that the governments should favor systematic observations of atmospheric electricity upon their telegraphic systems; that independent lines should be instituted for the study of earth currents; that the long subterranean telegraphic lines running north and south should be used also for this purpose; that simultaneous observations should be made over the surface of the globe. The Section on a standard of light were in favor of employing as a standard the light emitted by a square centimeter of melting platinum. J. T.

II. Botany and Zoology.

1. *The Lignified Snake from Brazil.* — The Popular Science Monthly for November, and the Bulletin of the Torrey Botanical Club, for the same month, have reproduced an account given in the French *La Nature* last April, of a remarkable phenomenon. The abstract in the Bulletin of the Torrey Botanical Club is the most condensed, and the essential part is copied here: the cut illustrating the object, however, is poor; that in the Popular Science Monthly is a somewhat better representation.

"The object represented is a small Brazilian reptile—the jaracaca—which was found within the trunk of an ipé-mirim, a tree of common occurrence in the province of Matto Grosso, to the north of the Amazons, where the specimen was discovered. The piece of wood containing the reptile, after an examination by the scientists of Rio de Janeiro, was taken to France by Mr. Lopez

Netto (Brazilian Minister to the United States) and placed in the hands of Mr. Louis Olivier, who, after a careful study of the specimen, submitted the results thereof to the Botanical Society of France.

"What is astonishing," says Mr. Olivier, in an article on the subject in La Nature, "is that the entire body of the snake is lignified,* the anatomical study that I have made of it having shown me that it consists of cells and fibres like those of the secondary wood which surrounds it. It is impossible to explain the fact by saying that there has occurred a formation of these elements in a hollow, which, having been traversed by the animal, has preserved the form of the latter; for on the piece of wood it is not only the contour of the snake that is visible, but, indeed, the whole relief of its body.

Just beyond the head there is likewise observed in relief a small cylinder which appears to represent the larva of an insect. It seems, then, that the snake, in pursuing the latter into a fissure in the tree, has insinuated itself between the wood and the bark into the cambium-layer, which is well known to be the generator of wood and secondary liber. The function of this cambium-tissue is two-fold; in the interior it gives rise, in a centripetal direction, to ligneous elements, the youngest of which are consequently found at periphery of the wood; but, toward the exterior, on the contrary, it produces, in a centrifugal direction, liber-fibres, elongated cells, and prosenchymatous elements, the youngest of which are therefore, situated on the internal surface of the bark. If, then, a foreign body be introduced as far as the external limit of the wood, it will, in a few years, become invested with a series of ligneous layers, which are themselves protected by an abundance of bark. Now, in the case under consideration, not only has there been an investment of concentric zones around the reptile, but, besides this, cells and ligneous fibres derived from the cambium-tissues have been substituted for the elements which constituted the external portions of the snake in measure as these have become absorbed. The places that these occupied have, as they gradually disappeared, been taken by secondary wood, whose hypertrophy is proved by the very relief of the snake's body." So far M. Olivier.

"The result, as in cases of petrifaction, is that in some parts of the body certain delicate details of the animal's organization are clearly visible. This is especially the case with regard to the nostrils and orbits, and to the arrangement of the scales and cephalic plates over the entire half of the surface of the head."

The narrative in the Popular Science Monthly adds from another source the names of the distinguished botanists who were present at the session of the Botanical Society of France, and who are said to have adopted the view of M. Olivier. The *Bulletin* of that Society in which the proceedings of that meeting is recorded have not yet come to our hands. We shall be much surprised if it fully bears out this statement.

* Except the center, in which are found the constituent elements of the animal.

Through the kindness of the Brazilian Minister, we have seen and examined the original specimen, and have been presented with an electrotype of it. It is a great curiosity. The resemblance to a snake is wonderfully close, although "the scales and cephalic plates," which Mr. Olivier identifies with those of a particular Brazilian snake, exist only in a lively imagination. The snake-like surface is covered by delicate meshes of woody fibers; and here and there particular fibers or woody threads can be traced from the body to the woody surface.

The adopted explanation requires us to suppose that a snake had forced his way between the bark and wood of a living tree, in a position exactly under a grub or larva; had perished there when within half an inch of its prey; was somehow preserved from decay, even to the eye-sockets and the markings of the skin, until a woody growth had formed, the elements of which replaced the whole superficial structure of the animal,—until the animal was lignified! Two other and more probable explanations have suggested themselves. One is, that the snake-like body is of the nature of a root, an aerial root, like those of a *Clusia* or a *Ficus*, which was making its way between bark and wood; and that the supposed larva is an incipient root of the same kind. The other supposes that the sinuous course is the track of a wood-eating larva or some kind of insect, the burrowing of which had not destroyed the overlying liber: consequently the new growth filling the space (except at certain points) had naturally assumed the likeness of a snake. This explanation was suggested by Professor Wadsworth of Cambridge, examining the specimen along with the writer; and it is to be preferred. Still, that head and neck should be so well outlined, and the former so well represent a pair of orbits, were surely most wonderful. But a close inspection of the electrotype showed that there had been some cutting away at the right side of the neck, and that the narrowing there was in part factitious; and less decisive indications suggested that other outlines had been touched up. The subsequent inspection of the original confirmed this; and likewise enlightened us about the eyes. For the left orbit was found to occur, not in a woody structure, like that of the right side, but in a dark material having the appearance of pitch or cement of some sort.

We may rest assured that whatever there may be which is factitious in this most curious *lusus naturæ*, originated before it came into the hands of His Excellency the Brazilian Minister at Washington. If these marks were not discerned by any of the Parisian *savants* in question—which we are slow to believe—they are less likely to have been noticed by Señor Lopez Netto, whose honor and good faith are incontestable. A. G.

2. *Flora Peoriana, Die Vegetation im Clima von Mittel Illinois.* Von FRIEDRICH BRENDEL.—An imperial octavo, of 107 pages, interesting for contents and very curious in form and origin, being in German, and printed at Buda-Pesth, at the printing-office of the Franklin Society of that town, and as being a part of the

fifth volume of the *Természetrajzi Füsetek*, edited by the National Hungarian Museum. In this treatise, Dr. Brendel discourses from his full knowledge of the topography, climate and vegetation of Illinois, and in particular of the relations of the latter to the former; and he ends with a Catalogue of the Flora around Peoria, his residence; adding to each species an abbreviated indication of its geographical range, also specifying species which on either hand approach the limits of his district. So that this is altogether an important contribution to the phytology of the United States. A. G.

3. *A Monograph of the Genus Lilium;* by HENRY JOHN ELWES, F.L.S., F.Z.S. Illustrated by W. H. Fitch, F.L.S. 1880. Elephant folio, London, March, 1877—May, 1880.—This sumptuous volume contains the most complete and best arranged account of the genus *Lilium* that has yet appeared. Every species known to the author, and by any means accessible to him, is here figured in natural size and colors, the drawing and coloring being in most instances from living specimens. Forty-six species are thus represented, together with several marked varieties and hybrids, in forty-eight full-page plates; with accompanying text giving scientific descriptions in Latin and English, the synonymy, the history of each species, its relations, etc. In an introduction are given a condensed history of the genus, a discussion of the general relations and arrangement of the species, their geographical distribution (illustrated by maps, and by an excellent photograph of a scene in the Northwest Himalayas where *Lilium polyphyllum* is found); and directions for their culture are also given. The author modestly and unduly distrusts his own judgment as a scientific botanist, and follows Mr. Baker's monograph as far as he finds it possible. He repeats Mr. Baker's Latin descriptions, with only occasional and generally very slight alterations, but wisely differs from him, not only in his limitation of species, but in their grouping. He recognizes but two main divisions, *Cardiocrinum* and *Eulirion*—the first including only the two very peculiar Asiatic species, *L. giganteum* and *L. cordifolium*. The other proposed sections, *Martagon*, *Isolirion*, etc., he considers too artificial to be kept up.

As American species he retains and illustrates the eastern *L. Philadelphicum*, *L. Catesbœi*, *L. Canadense*, *L. superbum* and *L. Carolinianum*. Of the more recently proposed *L. Grayi*, of the Southern Alleghanies, he had seen no specimen before the completion of his work. Of Pacific Coast species figures are given of *L. Washingtonianum* and var. *purpureum*, *L. Parryi*, *L. Humboldtii*, *L. pardalinum* with var. *angustifolium*, *L. parvum*, *L. maritimum* and *L. Columbianum*. The var. *purpureum* of the first species is obviously more than a variety; and it is only through mistake that *L. rubescens*, of the Botany of California, a quite different species of the Coast Ranges, has been supposed to have any connection with it. The forms of *L. pardalinum* are left somewhat in confusion, inasmuch as the plate which repre-

sents the type is lettered "*L. Californicum*" and entitled in the list of contents "Var. *Californicum*," while the var. *angustifolium* is figured as "*L. pardalinum*."

Of the Japan species that are recognized, *L. medeoloides* was founded upon what is pretty certainly only an undeveloped specimen of *L. avenaceum*. Oldham's Corean specimens, which are referred to *L. medeoloides*, and from which the figure is drawn, represent possibly a distinct species. The figure of *L. avenaceum* itself is perhaps the least satisfactory of any in the volume.

Great should be the praise of an amateur botanist who, inspired purely by love of the beautiful objects he cultivates, seeks to know them thoroughly, and notwithstanding other engrossing occupations, devotes his time and means to such an investigation as this, and enriches the science with such a noble monograph. The satisfaction which the author may take in the service he has rendered to botanists may be added to the gratification referred to in the dedication: "To my Wife, who first led me to the culture of plants, and whose love for Lilies suggested to me their study, I dedicate this book, in memory of the happy days I have spent in its preparation." S. W.

4. *F. A. Ford on the Pelagic fauna of Freshwater Lakes.*—A translation of Professor Ford's paper on this subject, from the Biologisches Centralblatt, ii, 299, is given in the Annals and Magazine of Natural History for October. Its principal points are the following: The pelagic, or deep-water fauna of the lakes of Europe is throughout very similar in species, and consists, fishes excluded, almost wholly of small Entomostracans of the Daphnia and Cyclops groups, with one Cypris. They have seasonal periodicity, some kinds disappearing in summer, or in winter, or spring or autumn, when they exist only in the state of resting-eggs. They come to the surface at night and descend again with the returning light, and thus making a daily migration. Weismann hence regards them as nocturnal animals which keep at the extreme limit of light; but it is better to say near this limit. The wide distribution of the fauna may have taken place by passive migration in the state of resting-eggs through the aid of migratory birds (ducks, grebes, gulls, etc.). The cause of the differentiation of the pelagic fauna is attributed to two phenomena—the daily migration above mentioned, and the action of the land-breeze and lake-breeze. At night, when the species are at the surface of the lake the land-breeze drives them to the middle of the lake; as day returns they sink and so escape the action of the lake-breeze which would drive them to the shore again. The action tends to make them pelagic and confine them to that region; and thus "a differentiation takes place by natural selection, until at last, after a certain number of generations, there remain only the wonderfully transparent and almost exclusively swimming animals, which we know." Two of the species, *Leptodora hyalina* and *Bythotrephes longimanus* appear, however, as held by Pavesi, to be of salt-water origin.

5. *A new genus of spherical Rhizopods.*—Mr. H. B. Brady describes, in the Magazine of Natural History for September, a white porcellanous spherical foraminifer, obtained by the *Challenger* expedition at a depth of 1,950 fathoms, in lat. 53° 55′ S., long. 108° 35′ E., or roughly about 25 degrees south of the southwestern corner of Australia. It is a tenth of an inch in diameter, and is made up of concentric layers each consisting of a large number of chamberlets arranged more or less regularly in single series. The chamberlets of the same layer communicate by short lateral stolons, those of successive layers by the pores which formed the superficial apertures of the previous layer. The surface is areolated, owing to the arrangement and the small convexity of the chamberlets. The material brought up in the dredge was a white diatom-ooze, composed chiefly of diatoms, radiolarians, sponge spicules, and other siliceous organisms, with seventeen species of rhizopods of arctic habit.

III. Astronomy.

1. *Transit of Venus.*—The daily papers have given quite fully the degree of success and failure had in observations of the Transit of Venus, especially in the United States, with more or less of detail of the observations themselves. There was upon the whole a much greater degree of success than could have been reasonably expected. At most of the observatories in the United States there were secured one or more of the four contacts. Particulars of these and of the physical appearances of Venus must, to have permanent value, be given by the observers themselves, in their own language.

The heliometer was thought by Lalande in the last century, even in its then imperfect form, to be the best instrument for observing the Transit. In its present perfected form it is thought by many astronomers, especially in Germany, to be the most powerful means we even now have of observing the Transit for the purpose of measuring the solar parallax. At New Haven the six-inch Repsold heliometer was used by Dr. Waldo and Professor Kershner continuously throughout the whole time of the Transit. The clouds interfered but little with this work, about 250 pointings of the instrument with corresponding readings being secured. These constituted twenty-seven more or less complete single sets of measurements across the sun, each set when complete being composed of eight pointings. There were in addition 20 direct measures of the diameter of Venus, 33 of the sun's diameter before and after the Transit, and 14 position angles near the first and fourth contacts.

Each of the four German parties had three-inch heliometers. At Hartford the clouds entirely prevented observations for the first hour, yet after that time five double sets of observations were secured by Drs. Müller and Deichmüller, together with various other valuable measurements.

At Aiken, the second northern German station, the clouds interfered somewhat more than at Hartford, but Dr. Franz is said to have secured three double sets of measurements.

At Martinique, the French party under M. Tisserand had a four-inch heliometer loaned by the Russian Government. Most unfortunately the clouds covered the sun immediately after the first contact, and apparently prevented further observation.

There are three southern stations armed with this instrument, no one of which has as yet been heard from. These are the two German parties under Professor Auwers at Punta Arenas in the Straits of Magellan, and Dr. Hartwig at Bahia Blanca, and the French party under M. Perrotin, which has a second Russian heliometer. Returns from these three parties are looked for with no little interest.

The American Government parties have been equipped with photo-heliographs under the belief that this instrument furnishes the best material for computing the solar parallax. The parties have all been reported to have been successful, except one not yet heard from, viz: that under Lieut. Very at Santa Cruz.

The French parties had photographic apparatus, though this was not regarded as an essential part of their equipment.

At a large number of observatories in the United States photographs have also been taken. At New Haven, Mr. Willson secured about 150; at Princeton, Prof. Young 188; at the Lick Observatory, 147 were taken. Whatever results can be had from photographs which we are now able to make have undoubtedly been secured.

The English and French parties relied upon contact observations. There were ten English parties, at Kingston (Copeland), Barbadoes (Talmage), Bermuda (Plummer), Madagascar (Perry), Cape Town (Gill), Aberdeen Road (Finlay), Montague Road (Marth), Brisbane (Morris), New Zealand (Tupman), S. American coast (Wharton). At Brisbane there was a total failure; Mr. Perry and Capt. Wharton have not been heard from. The other seven parties were successful.

There were nine French parties, Port au Prince (D'Abbaie), Puebla (Bouquet de la Grye), Martinique (Tisserand), St. Augustine (Perrier), Santa Cruz (Fleuriez), Chili (Bernardières), Chubut (Hatt), Rio Negro (Perrotin), and Oran (Janssen). Of these, Puebla, St. Augustine and Oran were successful, and Martinique failed.

There were four Brazilian stations, from none of which have we heard: St. Thomas (De Jeffe), Magellan (Cruls), Pernambuco (Lacaille), and Rio de Janeiro (De Souza Jacques). No Austrian, Russian or Italian parties were sent out.

In Europe the ingress was visible where it was clear weather, but unfortunately it was cloudy over England and France. In Ireland, at Potsdam and at Rome successful observations were made.

2. *Observations of the Transit of Venus at the Allegheny Observatory;* by S. P. Langley (in a letter to the editors, dated

Allegheny, Dec. 6, 1882).—The Transit of Venus was accompanied here by clouds, which came on between 1st external and 1st internal contact. Owing to these it was only certain that the latter occurred between $21^h\ 04^m\ 45^s{\cdot}9$ and $21^h\ 05^m\ 16^s{\cdot}0$ Allegheny mean time. The sky remained clouded till the close. A very curious and unexpected phenomenon was witnessed, however, during from six to eight minutes (counted from the time the planet was half on the disc). Upon the part of the planet *without* the sun, when the very faint bounding line of light, often observed before, was first becoming visible, as the planet was about half on, there was seen a distinct bright spot, extending through about 30° of the circumference and extending inward from the planetary limb to perhaps one-quarter of the radius. It is very noticeable that this brightness was not in a line joining the centers of the sun and planet, but was distinctly on one side. It was seen by me with the large Equatorial and a power of 244 on the polarizing eye-piece, and so plainly that I could even notice the gradation of the light, which was brightest at the circumference. Though my own observation was too clear to admit of doubt, there is independent confirmation in an observation by Mr. J. E. Keeler, who was observing near me with a much smaller telescope. We saw it independently, and independently estimated its position angle on the planetary disc within 10° of each other. What it was I cannot say. It is certain that it was seen.

3. *Elements of the great Comet of* 1882; by E. Frisby, Professor of Mathematics, U. S. N. (Communicated by Vice-Admiral Rowan, Sup't U. S. Naval Observatory.)—The following elements were computed from three observations made at the U. S. Naval Observatory; the first and last being made with the Transit circle, and the middle one compared with a known star which was afterwards observed on the Transit circle.

Wash. M. T.	App. α.	App. δ.
Sep. 19·9697877	$11^h\ 14^m\ 18^s{\cdot}94$	$-\ 0°\ 34'\ 29''{\cdot}7$
Oct. 8·7204363	10 28 6·63	−10 40 22·6
Nov. 24·7009228	9 6 16·22	−27 21 26·7

From these observations we deduce

Perihelion Time = Sep. 17·2228200 Greenwich mean time.

$$\left.\begin{aligned} \Omega &= 346°\ 1'\ 7''{\cdot}91 \\ \pi - \Omega &= 69\ 36\ 12{\cdot}79 \\ i &= 141\ 59\ 52{\cdot}16 \\ \phi &= 89\ 7\ 42{\cdot}70 \\ \log a &= 1{\cdot}9331366 \\ \log q &= 7{\cdot}8904739 \end{aligned}\right\} 1882\,0$$

period = 793·689 years

$$\delta\lambda \cos\beta = -\ 0''{\cdot}06 \qquad \delta\beta = +\ 0''{\cdot}01$$

$$x = r\,[9{\cdot}9951411] \sin(170°\ 42'\ 12''{\cdot}72 + v)$$
$$y = r\,[9{\cdot}9877234] \sin(262\ 46\ 57{\cdot}39 + v)$$
$$z = r\,[9{\cdot}4435130] \sin(\ 49\ 20\ 25{\cdot}11 + v)$$

The observations as given were afterwards corrected for parallax by means of elements previously computed. These elements

bear a considerable resemblance to Comet I, B. C. 371; and it may possibly be its third return, a very brilliant comet having been seen in full daylight A. D. 363.

Washington, Dec. 19, 1882.

IV. Miscellaneous Scientific Intelligence.

1. *Science—A new American weekly scientific Journal.*—It is announced that a new scientific journal will be shortly commenced at Cambridge, Mass., under the editorship of Mr. S. H. Scudder. It will be published weekly in large octavo in numbers of at least twenty-four pages. It is intended to occupy on this side of the Atlantic very much the same position long well filled by *Nature* in England. The scope of Science is broad. It is proposed to include condensed results of original researches, reviews of scientific works, weekly reports of scientific progress, of the contents of current periodical literature, and of the proceedings of scientific societies throughout the world; also papers on the practical applications of mechanics and physics, discussions of the methods of teaching the natural and physical sciences, and of other topics of general interest. The name of the editor-in-chief, and the long list of names that has been published of those who have promised to support this new journal is a guarantee that its standard of excellence will be high and that it will be well maintained. Such a journal cannot but exert a powerful influence for good in the development of American science. Among the names of those who have contributed largely to the pecuniary support of the undertaking, that of Mr. Alexander Graham Bell stands foremost, who is indeed mentioned as the founder of the enterprise. The publisher is Mr. Moses King, of Cambridge; subscription price, five dollars, post-paid.

2. *Report from the E. M. Museum of Geology and Archæology at Princeton*, for the year 1881–2, by Professor A. Guyot, Director.—The Princeton Geological and Paleontological collection has become one of great value and interest since its recent acquisition of 5,000 specimens of fossils; and, being well arranged, labeled and catalogued, it is one of the best in the country for instruction in these departments. The report just issued mentions the addition also of 2,600 specimens of minerals, from Mr. A. MacMartin, a graduate of the college, of a large collection of Archæological implements, representing the stone, bronze and iron ages of Switzerland, and the paleolithic and neolithic ages in France, and of ethnological collections from western America. The Report announces that a new number of the Bulletin will soon appear which will contain a description of the skulls of two large mammals, as yet unknown to science. A brief account of one, in advance of the fuller publication, is given by the authors on page 223 of the last volume.

3. *Proceedings of the Davenport Academy of Natural Sciences.* Vol. iii, Part 2. Pages 65–192, with 5 plates. 8vo. Daven-

port, Iowa, 1882.—This number of the Proceedings is devoted almost wholly to American Archæology, several important papers on this subject being published in it, and the plates being devoted to illustrations of them. Their authors are, G. Seyffarth, W. H. Pratt, C. T. Lindley, Dr. W. J. Hoffman, Rev. A. Blumer and Rev. J. Gass. Other shorter papers treat of the habits of Western Cicadæ, by J. D. Putnam; two new species of *Oxytheca*, from Southern California, by Dr. C. C. Parry; Geological notes by Mr. W. H. Pratt, and notices of Explorations in Idaho and Montana, by E. L. Berthoud.

Madeira Meteorologic, being a paper on the subject read before the Royal Society, Edinburgh, May 1, 1882, by C. Piazzi Smith, Astronomer Royal for Scotland. 84 pp. 12mo. Edinburgh. 1882. (David Douglas.)

The Climatic changes of later geological times. Part III. By J. D. Whitney. Memoirs of the Museum of Comparative Zoology, Cambridge, 1882.

Selections from Embryological Monographs, compiled by A. Agassiz, W. Faxon and E. L. Mark. 1. Crustacea, with 14 plates, 4to. Memoirs of the Museum of Comparative Zoology, Cambridge, vol. ix, No. 1. 1882.

Celestial charts made at the Litchfield Observatory of Hamilton College, Clinton, N. Y., by C. H. F. Peters. Charts 1 to 20. 1882.

Mineral statistics of Michigan for 1881. 262 pages 8vo, with numerous sections. Lansing, Michigan, 1882.

The Geological and Natural History Survey of Minnesota. 10th Annual Report, for the year 1881. N. H. Winchell, State Geologist. 254 pp. 8vo, with maps and plates. St. Paul, Minn., 1882.

First Annual Catalogue of the State Museum of California, Henry G. Hanks, State Mineralogist. 350 pp. 8vo. Sacramento, 1882.

Transactions of the Wisconsin Academy of Sciences, Arts and Letters, vol. v, 1877–81. 364 pp. 8vo. Madison, Wisconsin, 1882.

Transactions of the Linnæan Society of New York, vol. i, 168 pp. 8vo, with plates. New York, 1882.

Geological Survey of Newfoundland—Report of progress for the year 1881. Alexander Murray, C. M. G., Director. 16 pp. 8vo, with maps. St. John's, Newfoundland.

The Theory of the Gas Engine, by Dugald Clerk. 164 pp. 16mo. New York, 1882. (D. Van Nostrand).

Nachträge zur Dyas II, von Dr. Hanns Bruno Geinitz und Dr. J. V. Deichmüller. 46 pp. 4to, with 9 plates. Kassel and Berlin, 1882.

OBITUARY.

Franz von Kobell, the veteran mineralogist of Munich, died on the 11th of November last. The name of von Kobell has been identified with Mineralogy for more than fifty years, and the many excellent original papers, chemical, optical and crystallographic, which he has published, bear testimony to the industry that characterized his long life. In addition to minor researches he was the author of an elementary work on general mineralogy which has gone through five editions, of a history of mineralogy, and of a series of tables for determining mineral species which have been widely used and valued, and of which eleven editions have been published. Among the results of his optical work the *stauroscope* was the most important. Professor von Kobell was a man of unusual general culture, being a poet as well as mineralogist, and in his character he was most attractive; the many American students to whom he has shown kindness will never forget the impression which his genial courtesy made upon them.

MEAN ANNUAL RAINFALL.

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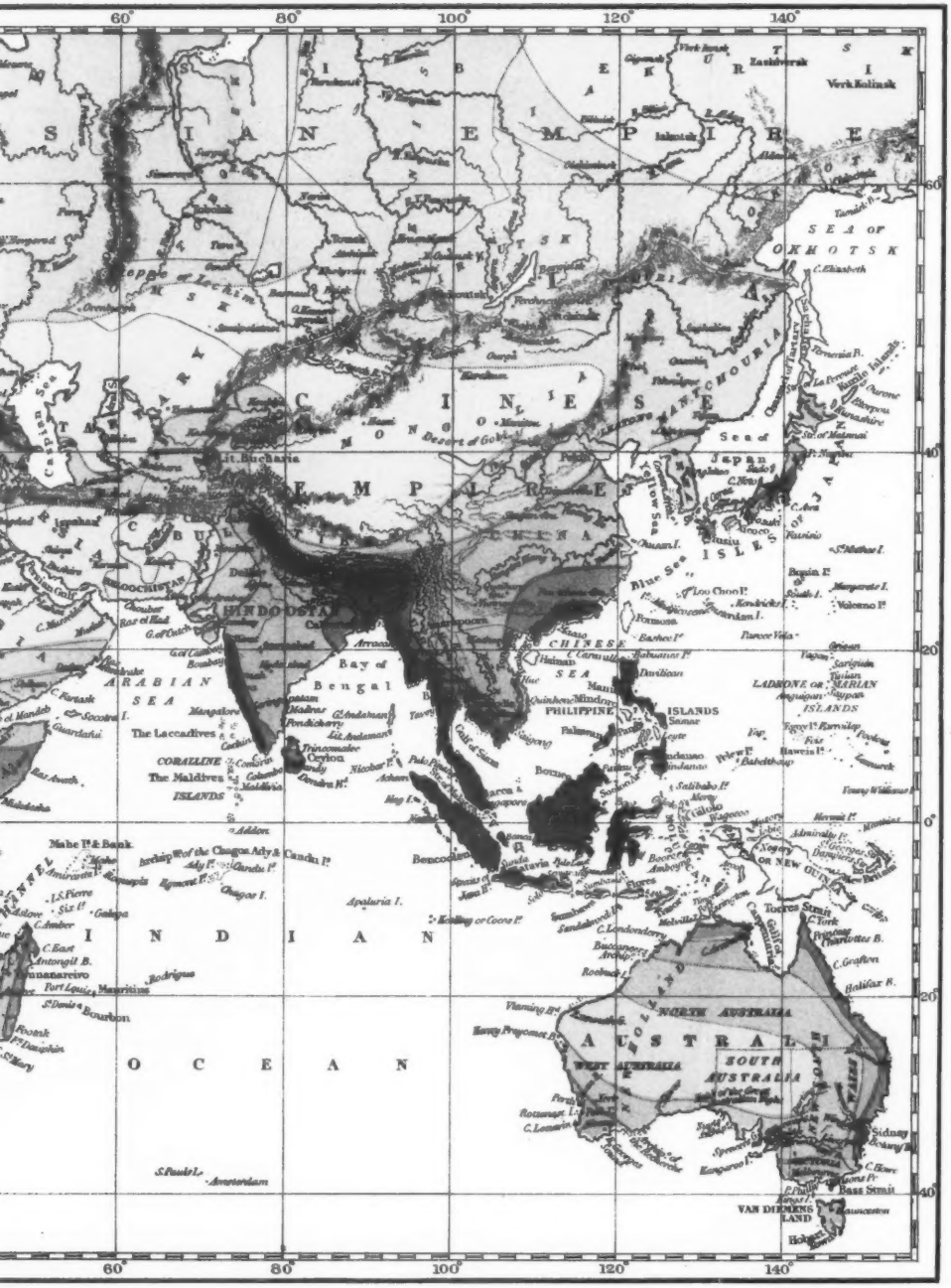
60°
80°
100°
120°
140°
SEA OF OKHOTSK
MANCHOURIA
CHINESE EMPIRE
Japan
HINDOOSTAN
ARABIAN SEA
Bay of Bengal
PHILIPPINE ISLANDS
LADRONE or MARIAN ISLANDS
CHINESE SEA
Blue Sea
Yellow Sea
Gulf of Siam
CORALLINE ISLANDS
The Maldives
The Laccadives
Ceylon
NEW GUINEA
Torres Straits
NORTH AUSTRALIA
WEST AUSTRALIA
SOUTH AUSTRALIA
NEW SOUTH WALES
VAN DIEMENS LAND
Bass Straits
INDIAN OCEAN
Mauritius
Bourbon
Amsterdam
Sidney
Hobart Town
Launceston
60°
40°
20°
0°